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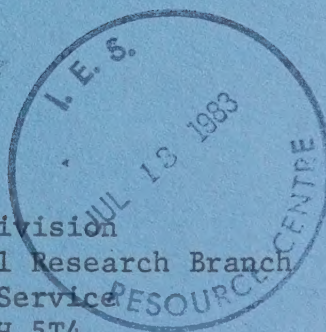
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METEOROLOGICAL ASPECTS OF AIRBORNE
POLLUTANT DISPERSION FROM THE PROPOSED
POPLAR RIVER THERMAL GENERATING
STATION, SASKATCHEWAN

by

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PREFACE

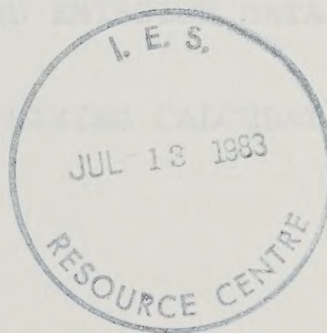
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INTRODUCTION

This study was undertaken, at the request of the Environmental Protection Service of Environment Canada, to determine the air quality implications of the proposed Poplar River thermal generating station for southern Saskatchewan (see Figures 1A and 1B for location). A 300 megawatt (MW) unit has been planned for initial installation and the projected total plant capacity is 600 or 1200 MW.

This report discusses the meteorological aspects of airborne pollutant dispersion from the proposed coal-fired generating plant. A detailed description is presented in Section 2 of the available meteorological data and analyses employed in this study. The techniques and results of dispersion modelling for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and suspended particulates are discussed in Section 3. In Section 4 the summary and concluding remarks are made.

Throughout the study, special consideration was given to the 'transboundary flow' situations - that is, situations which could cause air pollutants to be transported across the Canada-United States border. The report also gives special emphasis to such situations.

2. DISCUSSION OF METEOROLOGICAL DATA

The dispersion of air pollutants in the atmosphere is largely controlled by meteorological factors. As such, it is important that all available meteorological data be considered when preparing environmental assessments with respect to emissions to the atmosphere. On these data, various types of analyses can be performed to determine the dispersal capacity of the atmosphere in the particular geographical area of concern. The following material of this section deals with the available meteorological data and the preliminary analyses which have been completed for the Poplar River area of southern Saskatchewan and northeastern Montana.

To determine the surface wind climatology of the area hourly wind observations from five neighbouring weather stations to the proposed site were analysed. These stations are located at Rockglen and the airports of Swift Current, Moose Jaw, Regina and Estevan, Saskatchewan (see Figure 1A). Distributions of wind direction frequency by month and mean monthly wind speed by direction were prepared for each set of available data. Figures 2 and 3 exhibit the annual 'wind roses' (prepared from these distributions) which are the most common climatological representations of wind data. On these polar diagrams the frequencies of observed directions are proportional to the total length of the spokes, and the mean wind speed for each direction is denoted at the end of each spoke. Also, the percent calms and the mean wind speed for all directions are given below each

wind rose. It should be noted, that meteorologists define wind direction as that from which the wind is blowing.

The annual wind rose for Rockglen, shown in Figure 2, indicates that the prevailing winds are from the WSW-NNW sector (45.6% of the time) and from the S-SSE sector (15.9%). The predominant winds which would contribute to 'transboundary flow' of pollutants are from the WNW-NNW sector (28%).

The Swift Current annual wind rose (in Figure 2) indicates that the winds are generally from the S-WNW sector (57.2%) while the predominant transboundary air flow is from the WNW-NW sector (16.8%). For Moose Jaw, the annual wind rose shows that winds from the W-NW sector (33.4%) and from the SE (11.6%) prevail and that the predominant transboundary flow is again from the WNW-NW sector (24.8%).

In Figure 3 are the annual wind roses for Regina and Estevan. At Regina the prevailing winds are out of the W-NNW (35.6) and ESE-SSE (29.6%) sectors with predominant transboundary flow from the WNW-NNW sector (26.1%). The prevailing winds at Estevan are from the W-NNW (36.2%) and E-SE (24.3%) sectors with predominant flow towards the border from the WNW-NNW sector (28%).

The main features depicted by these annual wind roses (Figures 2 and 3) are that, in general, the air flows from the NW or SE quadrant in this area, with mean speeds of about 6.6 m/s or 5.8 m/s, respectively, while calms normally occur less than 2% of the time. The least prevalent winds and the lightest are from

the NE quadrant. Of special concern to this study is the air flow which could transport pollutants across the Canada-U.S. border, which has been called 'transboundary flow' above. Figures 2 and 3 show that the predominant winds, in this regard, blow out of the WNW-NNW sector about 20 to 30% of the time. It should also be noted that the strongest winds are generally associated with this sector, averaging approximately 7.0 m/s.

The strength of the surface winds is an important factor which contributes to air pollution potential. According to Gross (1970), persistent surface wind speeds equal to or less than 3 m/s contribute to high pollution potential. Although, no data on the persistence of light surface winds have been analysed for this area (due to the preliminary nature of this report) the wind rose data can be used for qualitative purposes. The mean annual surface wind speed for the area is about 6.2 m/s (average of 5 station annual means) and again, the frequency of calms is generally less than 2%. When this is compared with the results of a recent study of the Thompson, Manitoba area (Portelli, 1975), which revealed an annual mean surface wind speed of only 3.8 m/s and calm conditions 11% of the time, a relative appreciation of the potential for pollution can be obtained for the area.

For further detail on the surface winds in the area refer to Appendix A which contains the tabulations of wind direction frequency by month (Tables A.1 to A.5) and mean monthly wind speed by direction (Tables A.6 to A.10) for each station.

Also, the seasonal wind roses which were prepared for each station are included in this Appendix (Figures A.1 to A.5). The seasonal wind patterns varied only slightly from the annual patterns and as such did not warrant a full discussion. However, two significant seasonal trends should be noted; (1) in general, the mean wind speed is lowest in summer, and (2) winds from the sector WNW to NW occur more frequently in autumn and winter than in spring and summer.

Another set of climatological data is that derived from radiosonde flights. In order to assess the air pollution potential across Canada, the Atmospheric Environment Service has prepared tables of mixing height and wind speed within the mixed layer for all radiosonde stations in Canada as well as for some northern stations of the United States. The data are obtained from regular flights of the radiosonde balloon at 0600 and 1800 hrs Central Standard Time, which provide wind, temperature and humidity as a function of height. The data from the radiosonde station at Glasgow, Montana were used to study the dispersal capacity of the atmosphere in the area of the proposed plant since Glasgow is the closest station at 115 km (72 mi) to the southwest (see Figure 1B).

The dispersal capacity of the atmosphere depends mainly on its ability to mix a plume in the vertical which in turn is heavily dependent upon the rate of change of temperature with height in the ambient air. When the decrease of temperature with height (the "lapse rate") is greater than about $1.0^{\circ}\text{C}/100$ meters, the atmosphere is said to be unstable, i.e. mixing in the vertical direction is enhanced and the vertical extent of the

plume is relatively deep. An atmosphere with a lapse rate of about $1.0^{\circ}\text{C}/100$ metres is said to be neutral and the vertical extent of a plume is moderate. Lapse rates less than $1.0^{\circ}\text{C}/100$ meters indicate stable atmospheres which inhibit the vertical spread of a plume. Layers in the atmosphere with negative lapse rates, i.e. temperatures increasing rather than decreasing with height are called inversion layers. Therefore, because of their extreme stability, inversion layers above a plume act as barriers or 'lids' which prevent upward spread of the plume and consequently, are of particular interest in air pollution. Analyses of radiosonde data provide estimates of the frequencies of occurrence of such 'limited mixing' conditions - as they are most commonly referred to. Figure 4 presents a pictorial view of limited mixing conditions and illustrates the 'mixing height' concept. Descriptions on how mixing height is computed can be found in papers by Holzworth (1967) and McBoyle (1973).

The climatological tabulations of mixing height and wind speed are separated into two groups: those at sunrise (0600 CST) when the mixing height is usually near its daily minimum, and those in the afternoon (1800 CST) when the mixing height is usually at its maximum. For the purposes of this preliminary study, only the afternoon (maximum) mixing heights and wind speeds were examined.

The mean maximum mixing height for each month in the 4-year period analysed are shown in Figure 5 in chronological sequence. The seasonal trend is very clearly depicted: low mixing heights in winter and high mixing heights in summer.

Specifically, November to March are the months with the lowest mean mixing heights. The monthly mean extreme values are about 200 m and 2200 m. It should be noted, that the seasonal pattern has rather good consistency and a quasi-sinusoidal shape.

Averaging the monthly mean maximum mixing heights over the 4-year period affords the results shown in the histogram of Figure 6. The regularity of the seasonal pattern of Figure 5 gives support to the representativeness of the monthly mean maximum mixing heights shown in Figure 6. Again, the seasonal trend is as before and here the range of mean mixing heights is approximately 225 m to 1900 m with an annual mean of 1065 m. With respect to mixing height the most 'pollution-prone' months are November to March. These results are corroborated by those of Munn et al (1970) which indicated that in Saskatchewan "the most serious pollution potential occurs in autumn and winter when a stagnant continental arctic air mass lies over the region". However, as can be seen from the map of annual mean maximum mixing heights for Canada, shown in Figure 7, the area of southern Saskatchewan and northern Montana experiences, on average, some of the highest mixing heights. Note also, that this area is part of the 'ridge' of high mixing heights which stretches from Whitehorse through Calgary and Edmonton to Montana.

The histogram of Figure 8 exhibits the frequencies of occurrence of specified maximum mixing heights at Glasgow for all wind directions. Generally, it indicates that the highest frequencies of low mixing heights occur from about November to March as can be expected from the discussion of Figures 5 and 6. The seasonal trend of high frequencies of low mixing heights in

winter decreasing to summertime lows with increasing frequencies of high mixing heights also corroborates the information of Figures 5 and 6. From April to September high mixing heights occur very frequently, however, mixing heights greater than 800 m are rarely experienced in the winter months.

With regard to limited mixing conditions, the range of mixing heights considered significant is that from 200 to 600 m. An explanation for this will be given in Section 3. Then, the information of Figure 8 can be summarized as shown in Table 2.1, in terms of seasonal percent frequencies of various mixing height ranges below 600 m. In winter, the mixing heights are almost always under 600 m (94% of the time). However, 41% of the time the mixing heights are below 200 m which means that mixing heights from 200 to 600 m occur 53% of the time during this season. Autumn has the next highest frequency (29%) of mixing heights in this range, then spring (21%) and finally summer (8%). The annual average is 27%. Table B.1 of Appendix B contains the monthly frequencies of occurrence of specified maximum mixing heights at Glasgow, Montana, from which Figure 8 and Table 2.1 were constructed.

Figure 9 displays essentially the same type of information as does Figure 8, except that here only those mixing heights whose mixing layer winds were from a northerly direction (290° to 80°) have been considered. In other words, this is a histogram of the frequencies of occurrence of mixing heights which can affect pollutants transported from the power plant over the Canada - U.S. border into the State of Montana. Again,

Table 2.1: Seasonal frequencies (%) of occurrence of various maximum mixing height ranges for all wind directions, at Glasgow, Montana.

Mixing Height Range (m)	Spring	Summer	Autumn	Winter	Annual
L < 600	32	12	41	94	44
L < 400	22	7	25	84	34
L < 200	11	4	12	41	17
200 ≤ L < 600	21	8	29	53	27
200 ≤ L < 400	11	3	13	43	17
400 ≤ L < 600	10	5	16	10	10

Table 2.2: Seasonal frequencies*(%) of occurrence of various maximum mixing height ranges for winds from 290° to 80°, at Glasgow, Montana.

Mixing Height Range (m)	Spring	Summer	Autumn	Winter	Annual
L < 600	16	8	19	33	18
L < 400	10	5	10	27	13
L < 200	3	3	4	16	6
200 ≤ L < 600	13	5	15	17	12
200 ≤ L < 400	7	2	6	11	7
400 ≤ L < 600	6	3	9	6	5

* Joint frequencies of mixing height and wind direction (290° to 80°)

the same general features appear: winter with the highest frequencies of low mixing heights and negligible frequencies of mixing heights above 800 m; summer with high mixing heights occurring most frequently. As before, these data have been summarized in terms of seasonal percent frequencies of various mixing height ranges below the 600 m level, as shown in Table 2.2. In this case, mixing heights are less than 600 m only 33% of the time in winter as compared to 94% in Table 2.1. Then, with 16% below 200 m, the 200 to 600 m range is found 17% of the time in this season, while in autumn, spring and summer the percentages are 15, 13 and 5, respectively, averaging out to 12% annually. This means then, that the limited mixing situation (with mixing heights from 200 to 600 m) occurs with (northerly) transboundary air flow, on the average, approximately 12% of the time during the year; winter having the greatest potential for pollution with a 17% frequency of occurrence of such conditions. Table B.2 of Appendix B contains the monthly frequencies of occurrence of specified maximum mixing heights at Glasgow, from which Figure 8 and Table 2.2 were constructed.

Along with the mixing height data, mixing layer wind speed data have also been analysed for Glasgow. As can be seen from Figure 10, the mean monthly mixing layer wind speed pattern is bi-modal with peaks of about 8.5 m/s in both spring (May) and autumn (Oct.); the winter and summer low values are about 5 m/s and 6.5 m/s, respectively. This pattern is obviously attributable to the fact that well-organized storms with deep low pressures (developing strong winds) are more

frequent during the spring and autumn in the prairies.

Figure 11 contains the seasonal wind direction frequency patterns for mixing heights less than 1000 m at Glasgow. The spokes in this case are at 25° intervals since the available upper-air data were grouped into 30° sectors (i.e. $10-40^{\circ}$, $50-80^{\circ}$, $90-120^{\circ}$, etc.). Therefore, each spoke represents the frequency of occurrence of winds from a 40° sector which is centered about the spoke. These diagrams indicate that the most prevalent wind directions in mixing layers below 1000 m are roughly WNW to N and SE to E. Transboundary air flow, from the NW quadrant, occurs much more frequently during autumn (26%) and winter (31%) than in spring (17%) and summer (12%). The seasonal mean wind speeds (refer to Figure 10) are also shown in Figure 11 along with the seasonal frequencies of calms. Note, that winter has the lowest mean wind speed (about 5 m/s) and the highest frequency of calms (6.6%).

Figure 12 displays the annual wind direction frequency pattern for mixing heights less than 1000 m. The mean annual frequency of transboundary air flow, from the NW quadrant, is approximately 21% while from the SE quadrant it is about 15%. The pattern here is much the same as found in Figure 2 and 3 for the surface winds, with comparable frequencies of winds from the NW quadrant. Therefore, the surface wind direction data appears to be representative of the upper-level flow.

The frequency of ground-based inversions is another climatological index of pollution potential (Munn et al, 1970) as are the (afternoon) maximum mixing height and wind speed throughout this layer (Holzworth, 1967) and the strength of the surface winds.

Hosler (1961) has discussed the climatology of low-level inversions in the United States. In an appendix, he has included the percent frequencies of observations which indicated inversions (and/or isothermal layers) based at or below 500 feet (152 m) above the surface, for the period June 1957 to May 1959, inclusive. Also, he gives estimates of inversion occurrence as a percent of total time sampled (seasonal or annual). These values for Glasgow, Montana are shown in Table 2.3.

Table 2.3 Percent frequencies of inversion based below 500 feet at Glasgow, Montana (Hosler, 1961)

	SPRING	SUMMER	AUTUMN	WINTER
DAY*	7	4	17	56
NIGHT**	72	84	83	76
TOTAL TIME	33	32	44	48

* 00GMT (1800 hrs CST)

** 12GMT (0600 hrs CST)

The daytime inversion frequencies are higher in autumn (19%) and winter (56%) than in spring (7%) and summer (4%).

These percentages compare rather well with those of Table 2.1 for $L < 200$ m. The nighttime inversion frequencies appear more consistent throughout the year averaging about 79%. In terms of percent of total time, the seasonal cycle is one of more frequent inversions in autumn and winter than spring and summer. Again, winter stands out as having the highest potential for pollution with inversions occurring 48% of the time.

Since the data of Table 2.3 do not apply just for

surface-based inversion but also for those based below 500 feet, these frequencies are somewhat higher than if surface-based inversions alone had been considered. For comparison purposes, it is of interest to note that Holzworth (1974) has presented some climatological data on atmospheric stability in the United States which indicated that the percent frequency of daytime surface-based inversions is about 40% in winter for the Glasgow area of northern Montana. As we expected, this is lower than the value of Table 2.3 (56%).

3. DISPERSION MODELLING

Once pollutants are emitted from a stack at the pre-determined height, exit velocity and exit temperature, the state of the atmosphere governs their dispersion. The principle patterns of stack gas dispersion are generally classified descriptively in terms of the plume shape and the manner of their dispersion in the ambient atmosphere (Bierly and Hewson, 1962). The three plume dispersion models considered most likely to result in significant air pollution concentrations (Carpenter et al, 1971) are (1) the Coning Model; (2) the Inversion Breakup Model; and (3) the Limited Mixing Model. In the past, with relatively small stacks, the Coning Model was

expected to give rise to the most frequent cases of significant ground-level concentrations. However, investigators (Carpenter et al, 1971 and Pooler, 1965, for example) now believe that the critical model changes with increasing plant size and height, first to the Inversion Breakup Model associated with surface inversion breakup and then (for taller stacks) to the Limited Mixing or Trapping Model created by stable air aloft.

Estimates of ground-level concentration of SO_2 , NO_2 and suspended particulates were made using the above three models based on stack and emission data provided by the Environmental Protection Service (see Appendix c). Three plant configurations were considered: a 300 MW plant with one 425 ft (129.5 m) stack; a 600 MW plant with one 400 ft (122.0 m) stack and; a 1200 MW plant with two 400 ft stacks. A discussion of the concentration estimates follows under the appropriate model heading.

CONING MODEL

When unlimited mixing conditions exist, the plume shape is very much that of a 'cone'; hence, the term 'coning'. Dispersion calculations under such conditions have been made using the standard form of the Gaussian diffusion equation (as described by Turner, 1970). The plume rise calculations, to determine the effective stack height, were made employing the currently accepted plume rise formulae of Briggs (1969). Table 3.1 exhibits some effective stack height estimates for the two stack heights (HS), which have different heat emission rates (QH), as a function of wind speed (U) and stability. Note, that all effective stack heights are roughly between 200 and 500 m.

Table 3.1 Effective Stack Heights Computed Using Briggs' Plume Rise Formulae

HS (m)	QH (kcal/s)	U (m/s)	EFFECTIVE STACK HEIGHT (m)	
			STABILITY A-D	CLASS E-F
129.5	12500	5	427	317
		10	278	279
		15	229	260
		20	204	248
122.0	25000	5	482	359
		10	302	310
		15	242	286
		20	212	271

The curves of Figure 13 and 14 display the ground-level one-hour plume centerline concentrations of SO_2 and NO_2 , respectively, as computed by the Coning Model for stability class 'C' and a wind speed of 5 m/s. Note, that the straight lines on the figures refer only to limited mixing conditions which will be discussed later. A slightly unstable atmosphere (stability class 'C') was taken as a representative mean stability for the area and in Figure 10 it was shown that the lowest seasonal mean mixing layer wind speed was approximately 5 m/s. Under these conditions the plume from the 129.5 and 122.0 m stacks would rise to about 427 and 482 m, respectively (see Table 3.1). As can be seen from the curves of Figure 13, the estimated maximum SO_2 concentrations are approximately 45, 70 and 140 $\mu\text{g}/\text{m}^3$ for the 300, 600 and 1200 MW plant configurations, respectively. These are well within Environment Canada's Air Quality Maximum Desirable and Maximum Acceptable Objectives of 450 and 900 $\mu\text{g}/\text{m}^3$, respectively, for SO_2 . The computed maximum NO_2 concentrations for the three plant configurations, in order of increasing size, are 25, 40 and 80 $\mu\text{g}/\text{m}^3$, respectively, as shown in Figure 14. These are at least a factor of 5 lower than the Environment Canada Maximum Acceptable Objective of 400 $\mu\text{g}/\text{m}^3$. These peak SO_2 and NO_2 concentrations occur at approximately 6 or 7 km downwind. With north winds this would be roughly at the Canada-U.S. border, but the estimates of SO_2 and NO_2 concentrations under these conditions are relatively low.

If the wind speed were higher (5 to 20 m/s) and all other factors remained the same, then, similar curves to those of Figure 13 and 14 would be found. However, the peak concentrations would increase slightly and then decrease proportionally as the wind speed went from 5 to 20 m/s, while the downwind distance of peak concentration would gradually get closer to the source. Note, that although ground-level concentration is inversely proportional to wind speed and therefore should decrease from 5 to 20 m/s, plume rise decreases with increasing wind causing an increase in ground-level concentration making for only a slight overall change in the concentration.

The curves of Figure 15(A) to 15(I) exhibit the estimates of ground-level 24-hour suspended particulate concentration which were obtained by converting 1-hour ground-level estimates along plume centerline from the Coning Model, under stability class 'C' with a wind speed of 5 m/s. In all, there are 9 figures to cover the different plant configurations shown below in Table 3.2.

Table 3.2 Plant Configurations

	PLANT SIZE (MW)	ELECTROSTATIC PRECIPITATOR EFFICIENCY (%)
A	300	96
B	300	98
C	300	99
D	300	99.5
E	{ 600 1200	96 98
F	{ 600 1200	98 99
G	{ 600 1200	99 99.5
H	600	99.5
I	1200	96

There are actually 12 different possible combinations of plant size and ESP efficiency, however, some of the combinations result in the same emissions. For example, take case E. In going from 600 to 1200 MW, the particulate emission rate is doubled, but when the ESP efficiency is increased from 96 to 98% the emission rate is reduced by a factor of 2 and as such the two configurations would produce the same ground-level concentrations. Similarly, for cases F and G.

To obtain 24-hour estimates a ratio of the short-term Gaussian diffusion equation to the long-term Gaussian diffusion equation (see Smith, 1968 or Slade, 1969) was determined to be a function of downwind distance and stability and accordingly was used as a factor to reduce the 1-hour estimates. These 24-hour values represent crosswind average concentrations over a 22.5° sector for winds blowing continuously to that sector during a 24-hour period.

In making estimates of suspended particulate concentrations one must consider the background levels. The Air Pollution Control Branch of the Saskatchewan Department of the Environment has provided the results of their suspended particulate monitoring during 1972 and 1973 at Estevan, which is approximately 175 km due east of the proposed plant site. Table 3.3 contains the seasonal geometric means obtained from these data (sampling time of 24-hr) which are taken as representative background levels for the area. As should be expected in the prairies the spring and summer levels are relatively high.

Table 3.3 Background suspended particulate levels measured at Estevan, Sask. (1972 & 1973) by the Saskatchewan Department of the Environment

Season	Geometric Mean Concentration ($\mu\text{g}/\text{m}^3$)
Spring	62.9
Summer	76.2
Autumn	47.9
Winter	28.4
Year	53.4

The Environment Canada Maximum Acceptable Objective for suspended particulate levels is $120 \mu\text{g}/\text{m}^3$ for a 24-hour period. Taking this as the assimilative capacity (A.C.) of the atmosphere it can be seen that a large fraction of it is used up by the background levels. On Figures 15(A) to 15(I) the 4 horizontal lines labelled WINTER, AUTUMN, SPRING and SUMMER A.C. were obtained by subtracting the respective seasonal geometric mean background level from $120 \mu\text{g}/\text{m}^3$. Essentially, these are the seasonal assimilative capacities for further suspended particulate pollution since background levels have been accounted for. As an example, the ambient air quality objective of $120 \mu\text{g}/\text{m}^3$ would be exceeded in the area if emissions from the power plant, during the winter months, result in ground-level concentrations in excess of $91.6 \mu\text{g}/\text{m}^3$, since $28.41 \mu\text{g}/\text{m}^3$ are already present as background.

From Figures 15(A) to 15(I) it can be seen that the peak concentrations under coning conditions range from about $2.5 \mu\text{g}/\text{m}^3$, for the smallest plant with the highest ESP efficiency, to

approximately $60 \mu\text{g}/\text{m}^3$, for the largest plant with the lowest ESP efficiency. These peak values occur at a distance of about 5 to 7 km downwind and, as before, with north winds this places the peaks roughly at the Canada - U.S. border. Only in Figure 15(I) does the coning curve cross over the seasonal assimilative capacity lines and then only in spring and summer. Thus, for a 1200 MW plant with a 96% ESP efficiency the estimated peak concentrations, under coning conditions, plus the background levels may cause the Maximum Acceptable Objective of $\mu\text{g}/\text{m}^3$ to be exceeded during spring and summer. Referring to the wind roses for Rockglen, Figure A1 of Appendix A, it can be seen that the frequency of north winds is approximately 6 to 7 percent of the hours during spring and summer.

INVERSION BREAKUP MODEL

The data of Hosler (1961) on the frequency of occurrence of low-level and surface-based inversions, which were presented in Table 2.3 of Section 2, indicated that such inversions occurred about 79% of the time at night during the entire year. Since these inversions were based below 500 ft and since the afternoon overlying inversion layers were generally found to be above 500 m (1640 ft), as shown in Figure 6, it is safe to assume that the proposed stacks would emit during the night into the stable layer and not above it. The effluent would then be concentrated in a relatively shallow layer aloft at night and would not reach the surface in appreciable concentrations, as depicted by Figure 16 (a). Consequently, ground-level concentrations will be low on most nights.

However, shortly after sunrise, a phenomenon known as "fumigation" (inversion breakup) can cause high ground-level concentrations. Solar heating causes the daytime mixed layer to form next to the surface and grow thicker with time. When the top of the mixed layer reaches the plume, high concentrations are brought down to the ground suddenly, as shown in Figure 16(b). Estimates were made of maximum ground-level concentrations, employing the method suggested by Turner (1970), for all three constituents under consideration. These estimates are shown in Table 3.4 for downwind distances of 10 and 15 km for the possible plant configurations.

Although inversion breakup is likely to produce the highest concentrations at ground-level (Pooler, 1965), the area fumigated is likely to be a relatively narrow band, beneath the originally stable plume, with its closest point many kilometers away from the stack. Also, these fumigations are generally of short duration, persisting 30 to 45 minutes at distances up to 30 km (19 mi) from the emission source. Therefore, the chances of detecting fumigations of this type are very slight unless the same area is fumigated repeatedly. Furthermore, the estimates of Table 3.4 should be compared to one-half hour objectives, which have not been established by Environment Canada, as yet. If they are compared to the one-hour maximum acceptable objectives of 900 and 400 $\mu\text{g}/\text{m}^3$ for SO_2 and NO_2 , respectively, only the 1200 MW plant configuration would cause excessive concentrations and then only for NO_2 at the 10 km distance, which is probably about as close to the stack as one should make such estimates. Since no one-hour objectives exist for suspended particulates, there

Table 3.4 Estimates of maximum ground-level concentrations ($\mu\text{g}/\text{m}^3$) during morning fumigation (inversion breakup) for $u = 5 \text{ m/s}$

DOWNWIND DIST. (km)	PLANT SIZE (MW)	SO ₂	NO ₂	SUSPENDED PARTICULATES			
				96%	98%	99%	99.5%
10	300	263	158	158	79	40	20
	600	443	266	266	133	66	33
	1200	885	532	531	266	133	66
15	300	189	113	113	57	28	14
	600	321	193	193	96	48	24
	1200	642	386	386	193	96	48

is no basis for a reasonable comparison.

In summary, the potential for such fumigations to occur is quite high in the area under consideration, especially in summer when nocturnal inversions occur with a frequency of 84% (see Table 2.3) persisting throughout the day only 4% of the time. The climatology of mixing heights also supports this since the most frequent occurrence of the highest mixing heights is during summer.

LIMITED MIXING MODEL

Above it was shown that a surface-based inversion can be eroded from below by solar heating to produce a mixed layer (refer again to Fig. 16) which on growing to the height of the plume causes fumigation. As the height of this layer increases (with time of day to a maximum at about mid-afternoon) a limited mixing situation develops as long as the inversion aloft has not been destroyed entirely. Limited mixing or trapping conditions can also be caused by subsidence inversions, as in the Los Angeles area where such conditions persist for weeks and months, or by frontal inversions which occur for a day or less. At a coastal site a sea breeze can also produce such conditions.

As shown in Fig. 4, the height L of the base of the overlying stable layer, i.e. the top of the surface mixed layer, is called the "Mixing Height". Pollutants can mix in the vertical within the mixed layer of unstable or neutral conditions but cannot, unless they are extremely buoyant, penetrate its upper boundary. Therefore, because of vigorous vertical mixing beneath a restrictive boundary, ground-level concentrations under limited mixing conditions are higher than

they would be in the absence of limited mixing. Calculations of ground-level concentrations under limited mixing conditions were made using the technique suggested by Turner (1970), which is described in Appendix C.

To illustrate the effect of limited mixing conditions on ground-level concentrations, calculations were made employing the same pertinent parameters as used to determine the unlimited mixing (Coning Model) curves of Figures 13 to 15. Some of these results were then plotted on the appropriate figures. The sloped straight lines in Figures 13 to 15 represent the ground-level concentrations, of the respective constituents, under the noted limited mixing conditions. It should be made clear, that the point of highest concentration on each line is at the downwind distance $2X_L$, which is the distance at which the limited mixing model begins to apply, as explained in Appendix C. As can be seen quite clearly from all these figures, the maximum ground-level concentration under limited mixing conditions increases severalfold over the peak coning concentration as the mixing height decreases from 600 m to 200 m.

We should stop here for a moment to explain the statement made in Section 2 that the range of mixing heights considered important is that from 200 to 600 m, which will also explain why this is the range shown in Figures 13 to 15. In general, when an inversion exists aloft, the plume is restricted in the vertical. However, the plume may have sufficient momentum and buoyancy to penetrate. Therefore, using the method described by Briggs (1969), estimates were made of the maximum height Z_i (m) above

the stack, of an inversion base which could be penetrated by the plume. These estimates, which were made for an inversion layer in which the temperature increased 2°C (a relatively weak inversion) and wind speeds of 2 and 5 m/s are shown in Table 3.5 for the two possible stacks. Note, that Z_{tot} (m) represents the maximum height above the ground (i.e., $Z_{\text{tot}} = \text{HS} + Z_i$) of an inversion base which could be penetrated by the plume. These

Table 3.5 Plume Penetration Estimates

HS (m)	QH (kcal/s)	U=2m/s		U=5m/s	
		Z_i (m)	Z_{tot} (m)	Z_i (m)	Z_{tot} (m)
129.5	12500	59	189	37	161
122.0	25000	82	204	52	174

results show, that under normal limited mixing conditions (i.e., wind speeds ≥ 5 m/s in the mixed layer) the plume would be contained by inversion layers (aloft) as low as 175 to 200 m. Even with a low wind speed of 2 m/s (which would not be very likely in a limited mixing situation) the 200 m level is a realistic lower limit of an inversion base which would contain the plume.

The reason for selecting the 600 m upper limit is obvious from Figures 13 to 15. As the mixing height increases from 200 m, the maximum limited mixing concentration decreases approaching the maximum coning concentration and at about 600 m the two are reasonably close. Then, for higher mixing heights the Limited Mixing Model ceases to afford higher maximum concentrations than the Coning Model.

As was shown in Table 2.1 of Section 2, this 'core range' of mixing heights (from 200 to 600 m) occurred on 27% of the afternoons on an annual average, with seasonal high and low frequencies of 53% in winter and 8% in summer, respectively, when all wind directions were considered. However, for trans-boundary flow considerations (i.e. winds from 290° to 80°) the annual frequency drops to 12% with respective seasonal high and low frequencies of 17% in winter and 5% in summer (refer to Table 2.2 of Section 2).

Since the frequencies of occurrence of various mixing heights are given for 200 m height intervals (see Tables B.1 and B.2 of Appendix B), it is not possible to pinpoint a specific frequency with which any one of the Limited Mixing Model lines (of Figures 13 to 15) would occur. Nonetheless, if the data of Tables 2.1 and 2.2 of Section 2 are used in conjunction with Figures 13 to 15 some realistic estimates can be made. To simplify matters, only those situations which would cause the National Air Quality Maximum Acceptable Objectives to be exceeded (as noted on figures) will be discussed.

In Figure 13, SO_2 concentrations in excess of $900 \mu\text{g}/\text{m}^3$ result from emissions from the 1200 MW plant when the mixing height is approximately 200 to 250 m. This would occur at about 3.2 to 4.2 km downwind. To estimate the frequency of occurrence of mixing heights in this range it was assumed that the frequency distribution of mixing heights within a 200 m interval is relatively uniform when 20 m subintervals are taken. Then, considering mixing heights for all wind directions the frequency of occurrence of mixing heights from 200 to 250 m is approximately 4.2% annually (or 15 days per year on average). For the transboundary

flow case this mixing height range occurs about 1.6% annually (or 6 days per year). These frequencies were determined from Tables B.1 and B.2 of Appendix B. Note, that concentrations on U.S. soil never exceed the objective.

In Figure 14 the situations which produce NO_2 concentrations in excess of $400 \mu\text{g}/\text{m}^3$ are: (1) a 1200 MW plant with a mixing height of about 200 to 280 m and (2) a 600 MW plant with a mixing height of approximately 200 to 215 m. Considering all wind directions the annual frequencies of occurrence of the mixing height ranges in (1) and (2) above are 6.8 and 1.3% (or 25 and 9 days per year), respectively. For transboundary flow the annual frequencies are 2.5 and .5% (or 9 and 2 days per year), respectively. The above estimated frequencies of occurrence of SO_2 and NO_2 concentrations in excess of the respective objectives are summarized in Table 3.6.

For suspended particulates, the mixing heights which afford concentrations in excess of $120 \mu\text{g}/\text{m}^3$ (taking into account background levels), as derived from Figures 15(A) to 15(I), are given in Table 3.7.

PLANT SIZE
(MW)

 SO_2 NO₂

* Note, that a value to the left of the slash represents the total frequency whereas a value to the right indicates the frequency for transboundary flow.

Table 3.7 Estimates of mixing heights which cause suspended particulate concentrations (from the power plant) to exceed the seasonal assimilative capacities.

PLANT CONFIGURATION			MIXING HEIGHTS (m)			
	SIZE (MW)	ESP EFF'Y (%)	WINTER	SPRING	SUMMER	AUTUMN
A	300	96	200-240	200-270	200-300	200-340
B	200	98	-	-	200-220	200-240
C	300	99	-	-	-	-
D	300	99.5	-	-	-	-
E	{ 600 1200	{ 96 98 }	200-340	200-390	200-430	200-480
F	{ 600 1200	{ 98 99 }	200-240	200-270	200-300	200-340
G	{ 600 1200	{ 99 99.5 }	-	-	200-220	200-250
H	600	99.5	-	-	-	-
I	1200	96	200-480	200-530	200-590	200-650

The corresponding total frequencies of occurrence of these mixing heights are given in Table 3.8. Looking at the mean yearly frequencies it is quite clear that plant configurations E and I would be most detrimental to air quality with exceedence frequencies of 12.8 and 25.1% (or 47 and 92 days per year), respectively. Note, that configurations C,D and H show no excess concentrations. This table indicates that of all the seasons, winter will have the most severe pollution problem, even though the assimilative capacity is highest during the winter months. This is due to the rather high frequencies of occurrence of low mixing heights in this season (see Table 2.1 of Section 2).

Estimates were also made of the frequencies of occurrence of limited mixing conditions which could produce ground-level suspended particulate concentrations in excess of $120 \mu\text{g}/\text{m}^3$ on U.S. soil. To do this, the mixing height data were separated into four transboundary flow cases, for winds from:

- (i) 290 - 320°
- (ii) 330 - 360°
- (iii) 010 - 040°
- (iv) 050 - 080°

Next, the distances from the proposed plant site to the U.S. border were determined along the central direction of each of the above sectors, to give the following combinations of wind

Table 3.8 Estimates of the percentage frequency of occurrence of limited mixing conditions which could produce ground-level concentrations of suspended particulate in excess of Environment Canada's Maximum Acceptable Objectives ($120 \mu\text{g}/\text{m}^3$)

PLANT CONFIGURATION			MEAN SEASONAL PERCENTAGE FREQUENCY				
	SIZE (MW)	ESP EFF'Y (%)	WINTER	SPRING	SUMMER	AUTUMN	YEAR
A	300	96	6.1	5.5	2.0	4.6	4.4
B	300	98	0.0	1.1	0.6	0.0	0.4
C	300	99	0.0	0.0	0.0	0.0	0.0
D	300	99.5	0.0	0.0	0.0	0.0	0.0
E	{ 600 1200 }	96	21.5	12.4	4.9	12.5	12.8
		98					
F	{ 600 1200 }	98	6.1	5.5	2.0	4.6	4.6
		99					
G	{ 600 1200 }	99	0.0	1.1	0.7	0.0	0.5
		99.5					
H	600	99.5	0.0	0.0	0.0	0.0	0.0
I	1200	96	46.2	20.2	10.0	23.9	25.1

direction and distance to the U.S. border"

- (i) 305° - 11.3 km
- (ii) 345° - 6.6 km
- (iii) 025° - 7.1 km
- (iv) 065° - 14.8 km

Then, the mixing heights which afford concentrations on U.S. soil in excess of the seasonal assimilative capacities were determined for each plant configuration using the above four distances to the U.S. border. Finally, the joint seasonal frequencies of occurrence of these mixing heights and the above wind directions were determined and the four values were summed for each plant configuration to give Table 3.9.

As before in Table 3.8 plant configurations E and I show up in Table 3.9 with the highest annual exceedence frequencies - 3.1 and 9.1% (or 11 and 33 days per year), respectively. And in this case, configurations B, C, D, G and H afford no excess concentrations, whereas in Table 3.8 configurations B and G did pose a slight problem. For this transboundary flow case, there is only a slight variation in the seasonal exceedence frequencies. By examining Tables 2.1 and 2.2 of Section 2 along with Table 3.3 of Section 3 one can understand why Tables 3.8 and 3.9 show such a different seasonal trend. From Table 2.1 the total frequencies of mixing heights 200 to 600 m are 53, 21, 8 and 29% of the time for the winter to autumn seasons, respectively. From Table 2.2 the seasonal joint frequencies of mixing heights 200 to 600 m and winds 290 to 80° are 17, 13, 5 and 15%, respectively. Since the winter frequency drops drastically for transboundary flow and since the assimilative capacity is highest

Table 3.9 Estimates of the percentage frequency of occurrence of limited mixing conditions which could produce ground-level concentrations of suspended particulates, on U.S. soil, in excess of Environment Canada's Maximum Acceptable Objective ($120 \mu\text{g}/\text{m}^3$)

PLANT CONFIGURATION			MEAN SEASONAL PERCENTAGE FREQUENCY				
	SIZE (MW)	ESP EFF'Y (%)	WINTER	SPRING	SUMMER	AUTUMN	YEAR
A	300	96	0.0	0.9	0.5	0.2	0.4
B	300	98	0.0	0.0	0.0	0.0	0.0
C	300	99	0.0	0.0	0.0	0.0	0.0
D	300	99.5	0.0	0.0	0.0	0.0	0.0
E	{ 600 1200	{ 96 98}	1.8	5.3	2.7	2.4	3.1
F	{ 600 1200	{ 98 99}	0.0	1.0	0.5	0.2	0.4
G	{ 600 1200	{ 99 99.5}	0.0	0.0	0.0	0.0	0.0
H	600	99.5	0.0	0.0	0.0	0.0	0.0
I	1200	96	9.6	10.6	8.6	7.6	9.1

in winter, it does not stand out as the most affected season as in Table 3.8. Note, that in winter the 200-600 m mixing height range occurs much more frequently with southerly flow than with northerly flow (36% of the time as compared to 17%). The frequencies in the other seasons are reasonable similar for both types of flows. On referring to Table 3.9 again, it can be seen though, that for transboundary flow the spring season would be more affected by suspended particulate pollution than the other seasons by only a slight margin.

Another manner of presenting limited mixing calculations is shown in Figures 17, 18 and 19. The contours are lines of constant mixing depth with maximum ground-level concentrations and wind speed along the ordinate and abscissa, respectively. On each figure three ordinate scales have been used corresponding to the three plant sizes as marked. The calculations for Figure 17 and 18 were made for stability class 'A' in the mixed layer since it represents the most unstable condition likely to be encountered in the area. Relative to the rest of Canada, southern Saskatchewan has one of the greatest number of hours of bright sunshine, especially in summer. However, for the 24-hour estimates required for Figure 19, stability class 'C' was taken as most representative of a complete day.

Figures 17 to 19 show that with decreasing wind speed and decreasing mixing height maximum ground-level concentrations increase. The point of maximum concentration can vary from about .9 to 2.0 km downwind of the source for mixing depths of 200 to 900 m, respectively, for the results shown in Figure 17

and 18. For Figure 19, this downwind point varies from about 3.2 to 10.6 for mixing depths of 200 to 600 m. It was shown earlier that 200 m was a reasonable estimate of the base of inversion layers which would contain the plume. Thus, it can be seen from Figure 17 to 19 that beneath the 200 m contour there are several combinations of plant size, mixing height and wind speed (bounded by $u = 1$ m/s) that give rise to SO_2 , NO_2 and suspended particulate concentrations, respectively, in excess of the maximum acceptable objectives, under the respective atmospheric stability conditions. These combinations are summarized in Table 3.10.

This table indicates, for example, that if the plant size is 600 MW and a mixing height of 200 m exists then the SO_2 concentrations would be in excess of the $900 \mu\text{g}/\text{m}^3$ objective if the mean wind speed in the mixed layer is less than or equal to 6.0 m/s. In general, Table 3.10 shows that with increasing plant size there is an increase in the number of possible combinations of mixing height and wind speed which would cause excessive concentrations.

In summary, the limited mixing model is significant for 3 reasons:

- (1) Resulting maximum surface concentration may be several times that estimated for coning conditions.
- (2) Actual stack height is a relatively minor determinant of plume height. While high stacks offer material advantages for most meteorological

Table 3.10 Combinations of plant size, mixing height and wind speed which may give rise to excess† ground-level concentrations.

PLANT SIZE (MW)	L (m)	WIND SPEED RANGE (m/s) (from 1.0 m/s to noted value)		
		SO ₂	NO ₂	SUSPENDED PARTICULATES*
300	200	2.5	4.5	5.6
	300	1.5	2.5	2.5
	400	-	1.5	1.5
600	200	6.0	8.5	11.5
	300	2.8	4.5	4.8
	400	1.8	3.0	2.6
	600	1.0	1.8	1.2
1200	200	9.5	17.0	> 18.0
	300	5.4	9.0	9.5
	400	3.5	6.0	5.2
	600	2.0	3.5	2.2
	900	1.2	2.0	

* 96% electrostatic precipitator efficiency.

† "excess" here refers to constituent concentrations greater than the respective Air Quality Objectives.

conditions, plume height during trapping conditions is primarily determined by the elevation and magnitude of the inversion aloft.

- (3) Maximum surface concentrations may persist 2-4 hours, usually occurring from mid-morning to mid-afternoon and relatively near the plant, generally less than 10 km.

Also, it should be noted that the significant differences between the Inversion Breakup Model and the Limited Mixing Model are that the former affords high surface effluent concentrations for short durations, about 30-45 minutes just after sunrise, at a variable downwind distance, generally 15-30 km, as compared to what was stated in point (3) above about the latter.

Furthermore, the magnitude of surface concentrations alone does not necessarily establish the criticality of a particular plume dispersion model. Frequency of occurrence the model and duration of the resulting concentration must also be considered. With this in mind, and in view of the material presented in this section, there should be no doubt that the Limited Mixing Model is the critical plume dispersion model for the proposed power plant.

4. SUMMARY AND CONCLUSIONS

A preliminary investigation was made of the meteorological factors affecting the dispersion of air pollutants from the proposed

Poplar River thermal power plant for southern Saskatchewan. Special consideration was given to transboundary air flow since the proposed site is only 4 mi (6.4 km) north of the Canada-U.S. Border. Also, particular attention was paid to 'limited mixing' conditions, in which a stable layer above the plume prevents further upward dilution of the plume. Vertical mixing takes place in the 'mixed layer' beneath the stable layer and therefore, higher ground-level concentrations occur than in the absence of limited mixing. It was shown that ground-level concentrations of SO_2 , NO_2 and suspended particulates, in excess of the respective Maximum Acceptable Objectives for Canada, could occur under various (restricted) ranges of limited mixing conditions depending on plant size: the range increasing with increasing plant size. Estimates indicated that limited mixing conditions could produce, on average, excess 1-hour ground-level SO_2 concentrations for the 1200 MW plant about 15 days per year in total and about 6 days per year with transboundary air flow. For NO_2 , the 600 and 1200 MW plants were shown to cause excess concentrations about 5 and 25 days per year, respectively, in total and approximately 2 and 9 days per year with transboundary flow. These situations could occur for several hours in mid-day. No excess SO_2 concentrations were estimated to reach U.S. soil, however, for the 1200 MW plant excess NO_2 concentrations resulting from

limited mixing conditions extended to about 11 km downwind.

Similar estimates, converted to a 24-hour period, indicated that ground-level suspended particulate concentrations greater than $120 \mu\text{g}/\text{m}^3$ could result from the operation of the 300, 600 and 1200 MW plants with greatly varying frequencies depending on the ESP efficiency. A revised and condensed form of Table 3.8 is shown below (Table 4.1) indicating the average number of days per year that excess concentrations could occur.

Table 4.1 Total number of days per year, on average, that suspended particulate concentrations could exceed $120 \mu\text{g}/\text{m}^3$ under limited mixing conditions.

PLANT SIZE (MW)	ESP EFFICIENCY (%)			
	96	98	99	99.5
300	16	1	-	-
600	47	17	2	-
1200	92	47	17	2

The conclusion that can be made here is that the Canadian Maximum Acceptable Objective for suspended particulates is achieved for the 300 and 600 MW plants with ESP efficiencies of 99 and 99.5%, respectively. For the 1200 MW plant a 99.5% ESP efficiency may cause values in excess of $120 \mu\text{g}/\text{m}^3$ on about 2 days per year.

Also, a revised form of Table 3.9 is shown below (Table 4.2) to clearly indicate the potential impact of

suspended particulate emissions on U.S. soil. It appears here that the 600 and 1200 MW plants could cause significant suspended particulate pollution on U.S. soil. However, if the ESP efficiency is 99% or greater then the possibility of causing concentrations to exceed $120 \mu\text{g}/\text{m}^3$ on U.S. soil is almost entirely removed.

Table 4.2 Number of days per year, on average, that suspended particulate concentrations could exceed $120 \mu\text{g}/\text{m}^3$, on U.S. soil, under limited mixing conditions.

PLANT SIZE (MW)	ESP EFFICIENCY (%)			
	96	98	99	99.5
300	1	-	-	-
600	11	1	-	-
1200	33	11	1	-

In summary, the areas most likely to be affected by high pollution levels were shown to be generally to the NW and SE of the proposed plant site, according to the wind climatology of the area. Also, the seasonal variation of pollution potential indicated winter to be most 'pollution-prone'. The manner in which the results of the suspended particulate dispersion modelling were presented clearly indicated the winter pollution problem.

ACKNOWLEDGEMENTS

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FIGURES

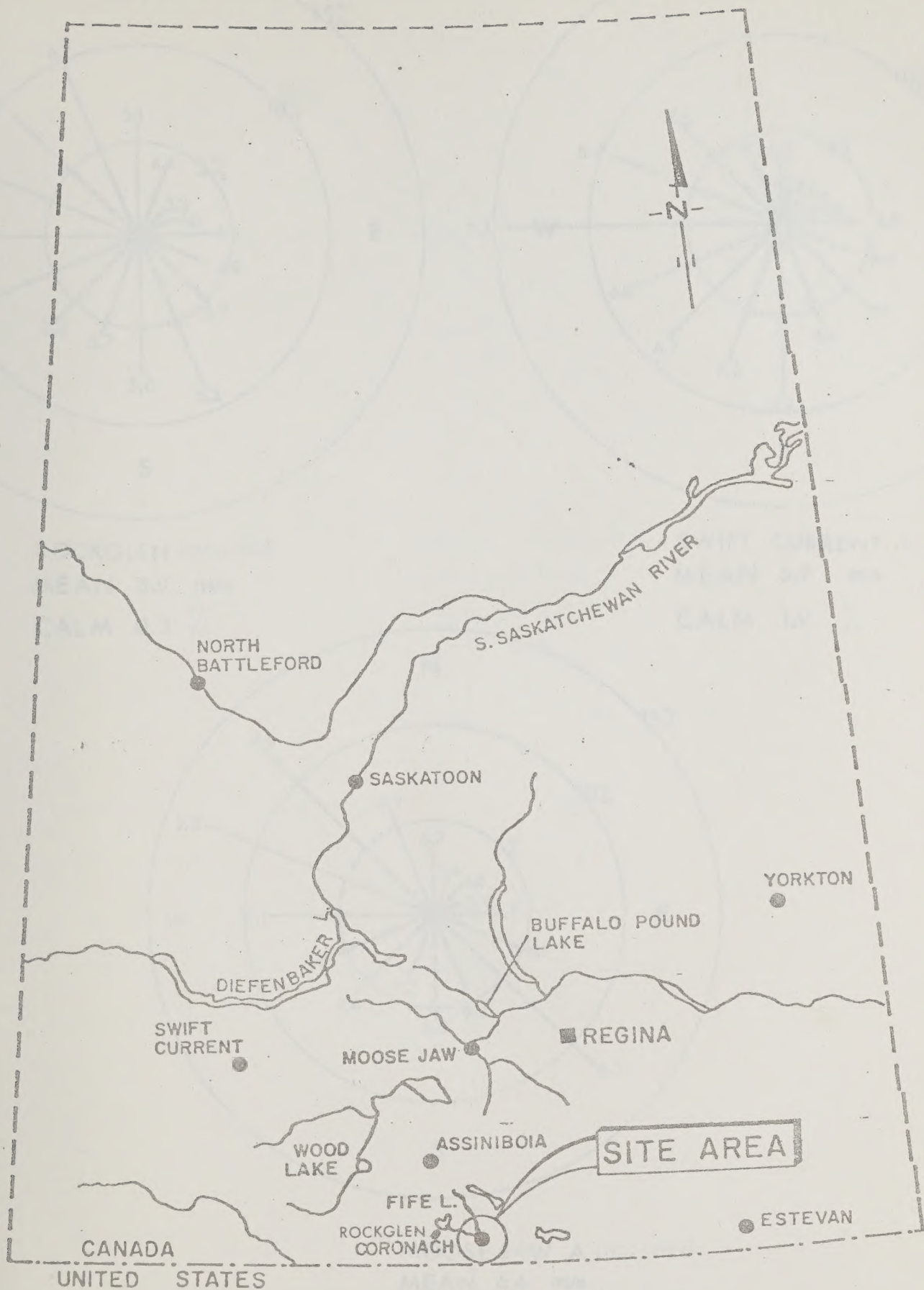
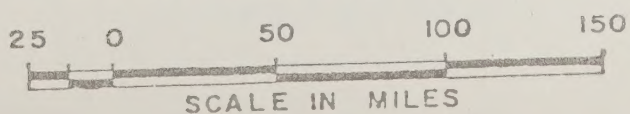
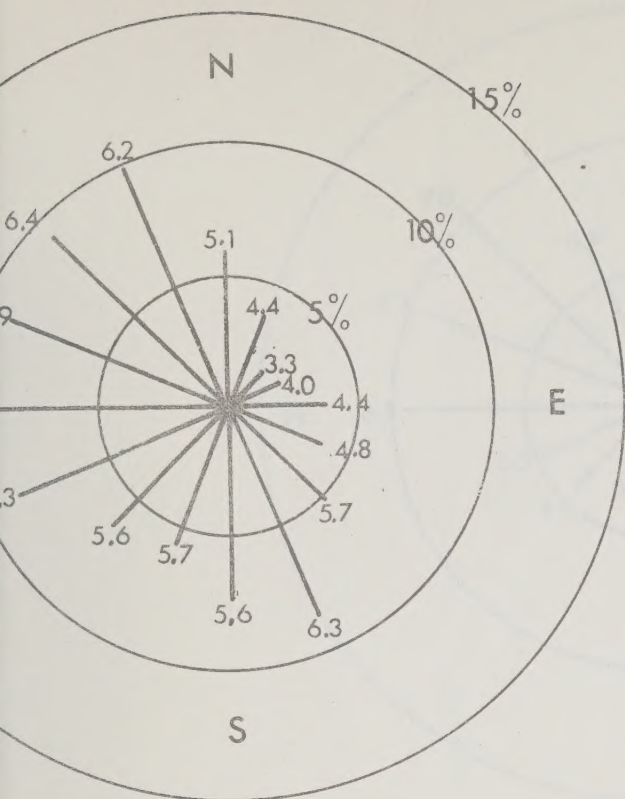


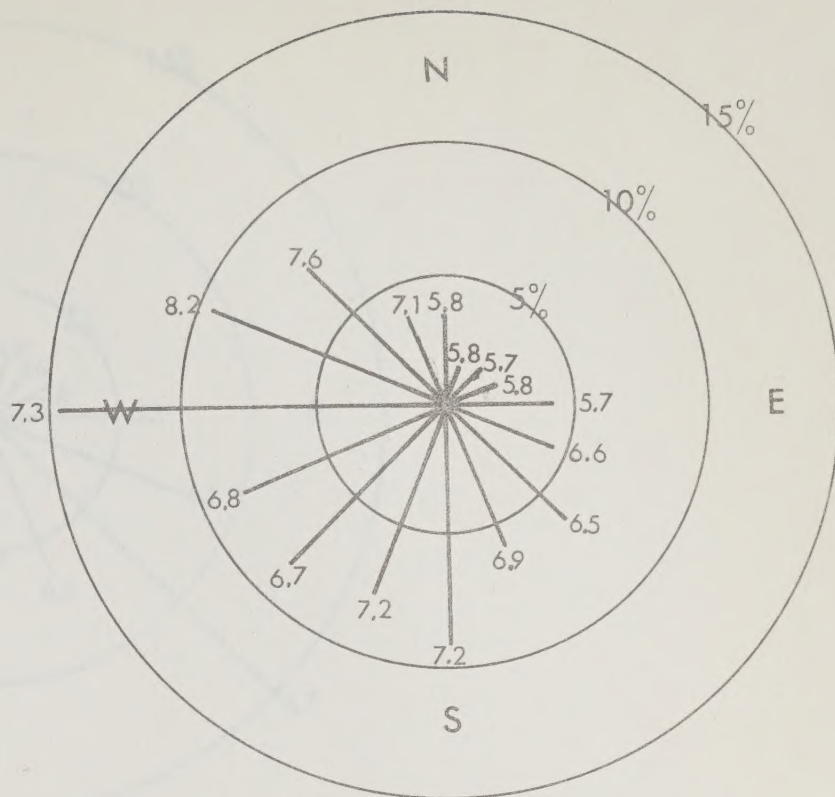
FIGURE 1A

KEY MAP

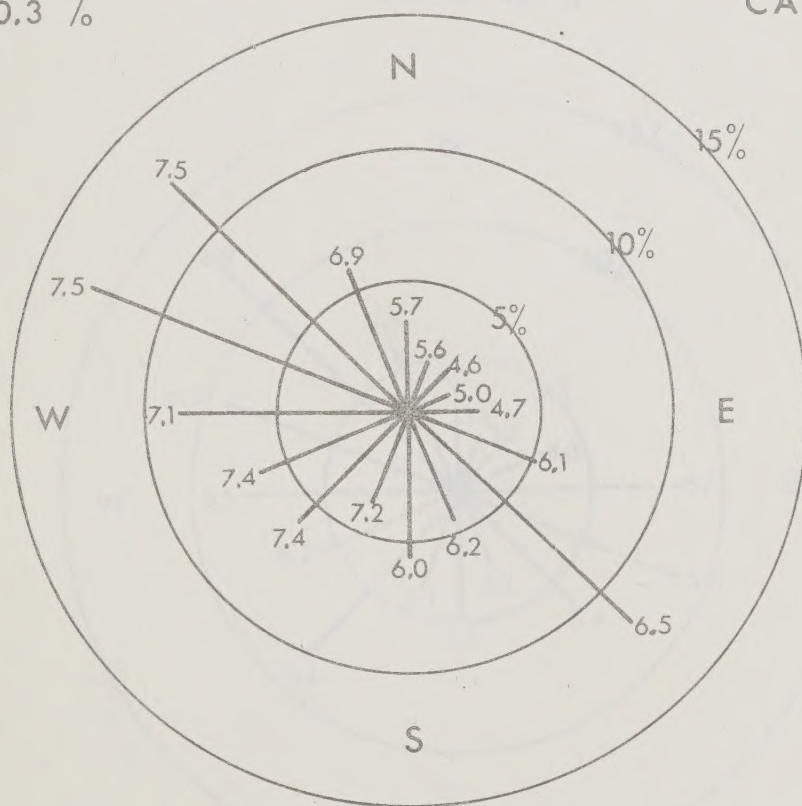




ROCKGLEN (1971-1973)
 MEAN 5.9 m/s
 CALM 0.3 %

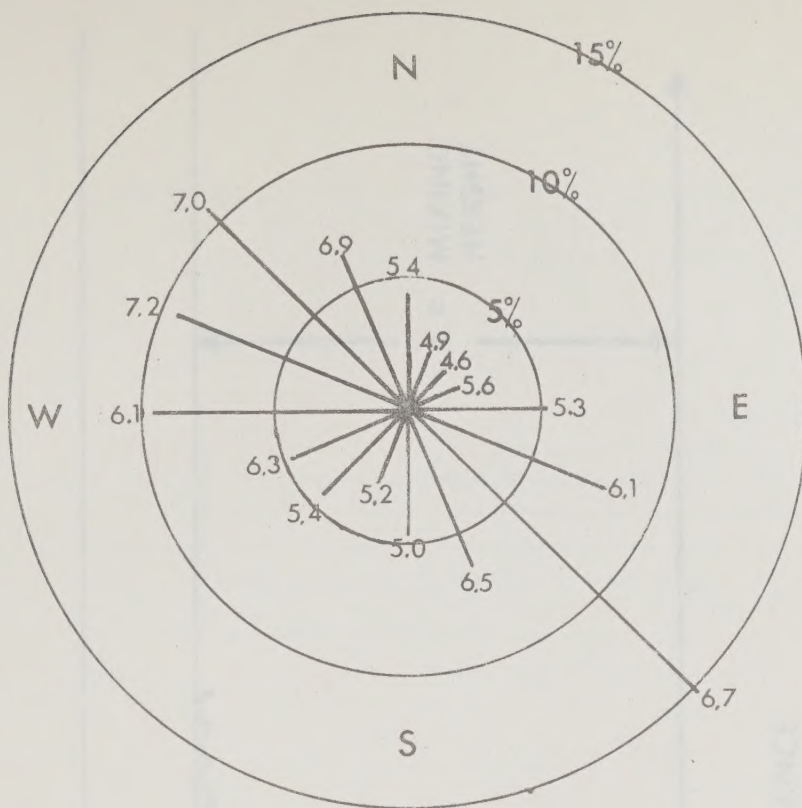


SWIFT CURRENT A (1964-1973)
 MEAN 6.9 m/s
 CALM 1.9 %

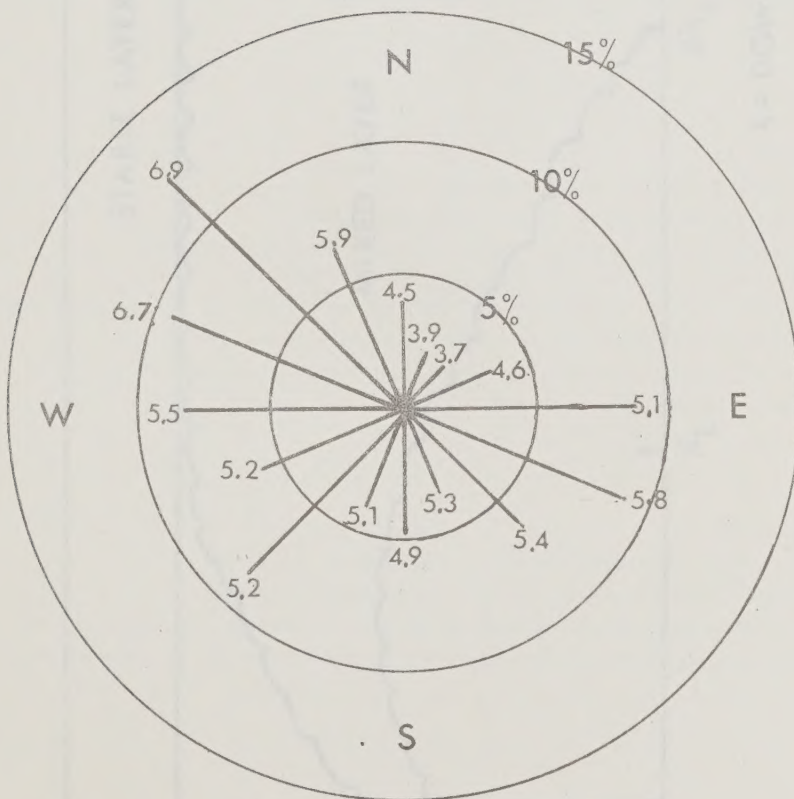


MOOSE JAW A (1957-1966)
 MEAN 6.4 m/s
 CALM 6.3 %

FIGURE 2
 ANNUAL WIND ROSES



REGINA A (1957-1966)
 MEAN 6.2 m/s
 CALM 1.6 %



ESTEVAN A (1964-1973)
 MEAN 5.6 m/s
 CALM 1.0 %

FIGURE 3
 ANNUAL WIND ROSES

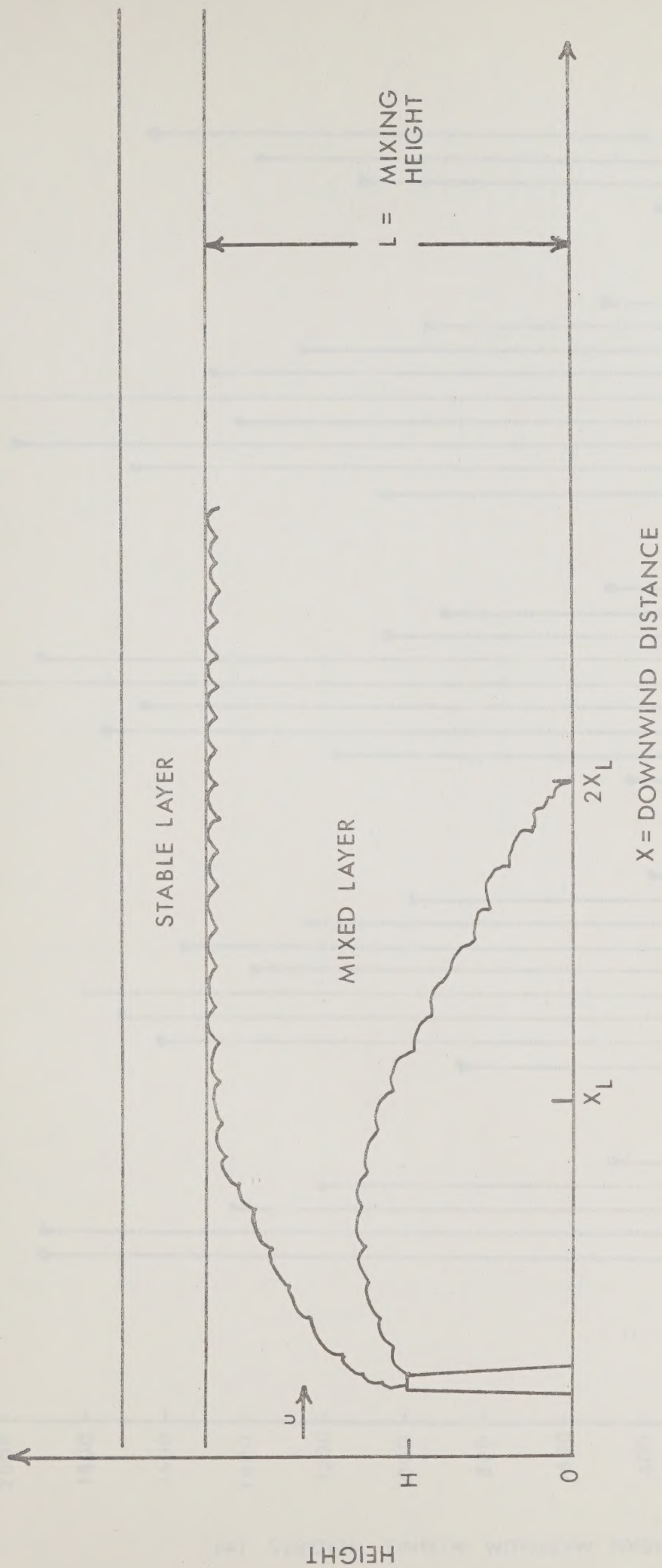


FIGURE 4 PICTORIAL VIEW OF LIMITING MIXING CONDITIONS

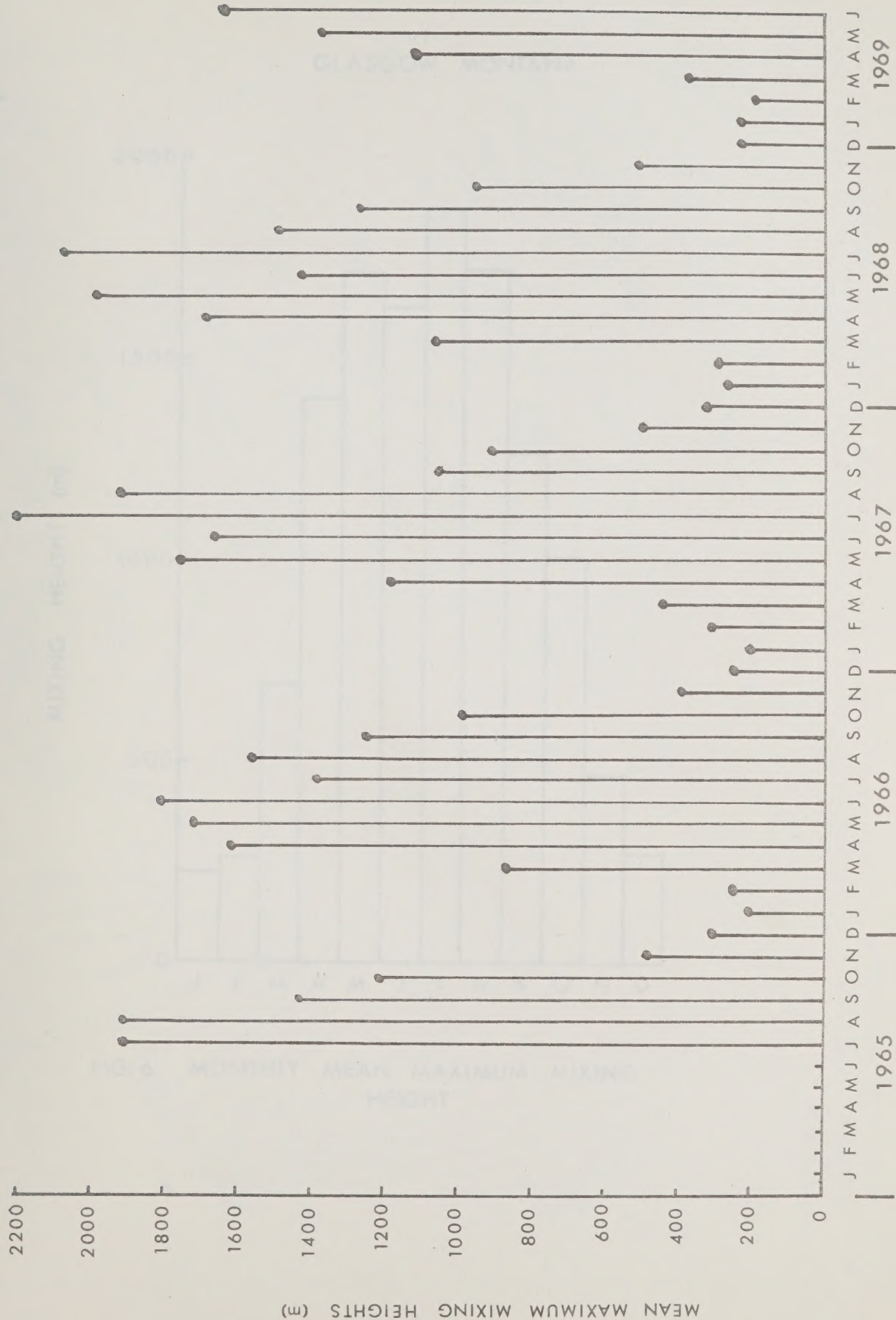


FIGURE 5 MONTHLY MEAN MAXIMUM MIXING HEIGHTS AT GLASGOW, MONTANA

GLASGOW, MONTANA

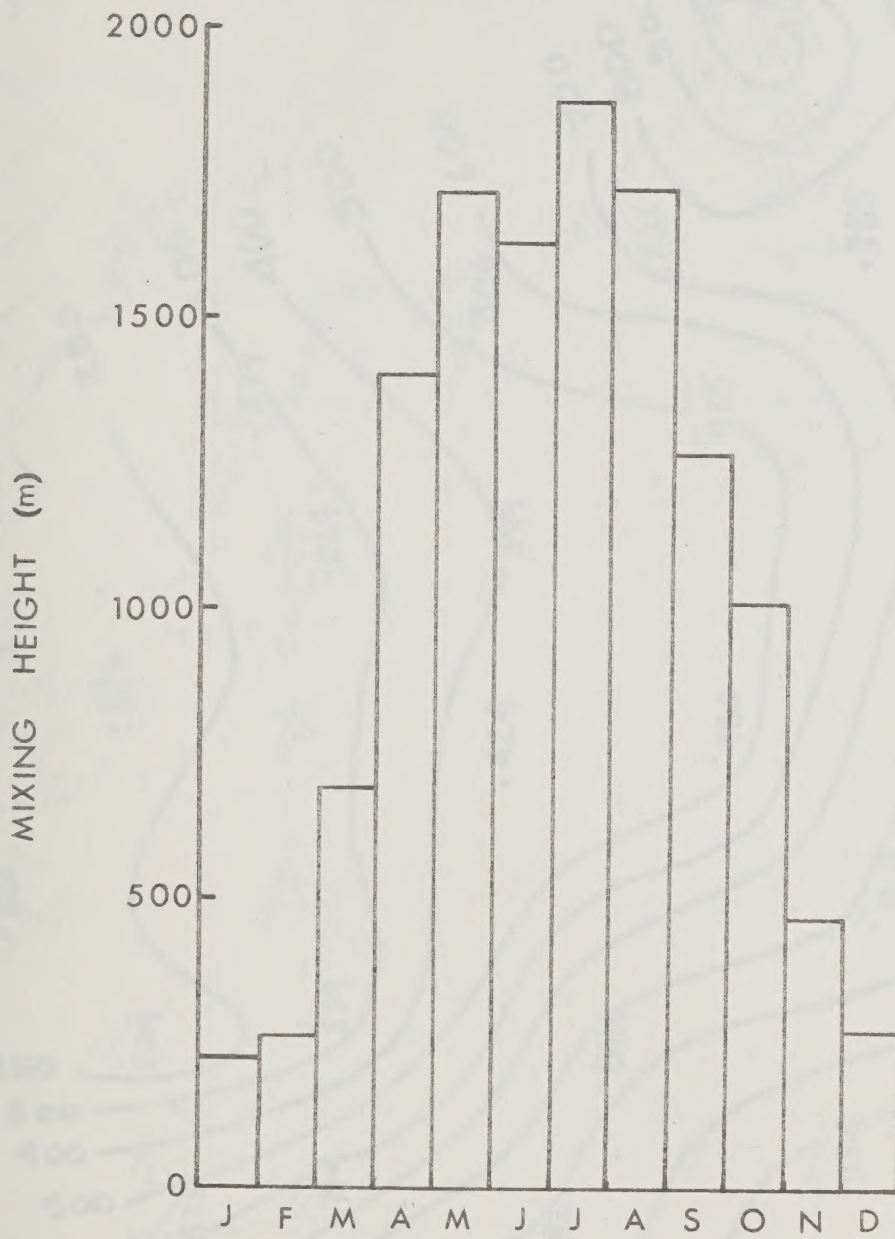


FIG. 6 MONTHLY MEAN MAXIMUM MIXING HEIGHT

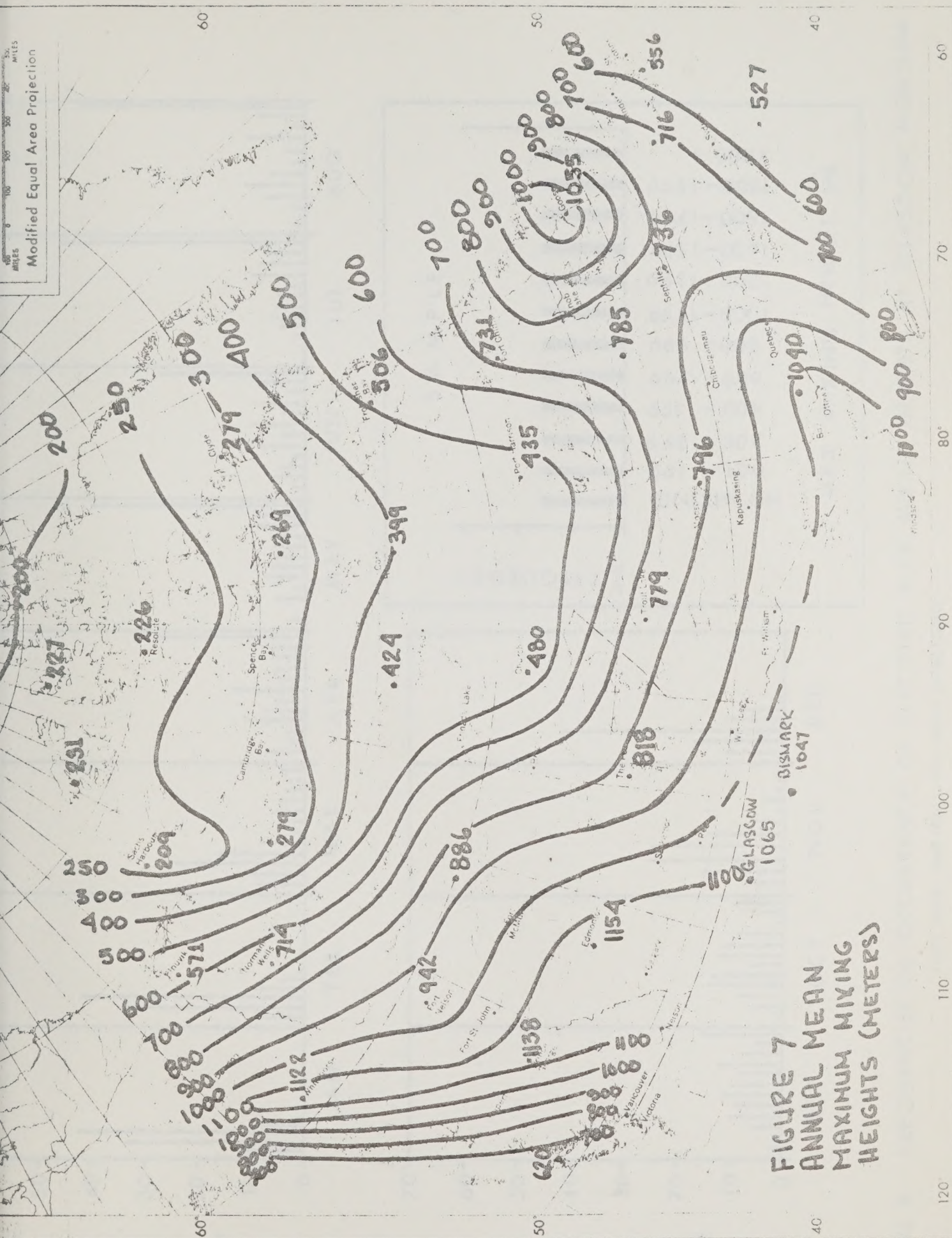


FIGURE 7
ANNUAL MEAN
MAXIMUM MIXING
HEIGHTS (METERS)

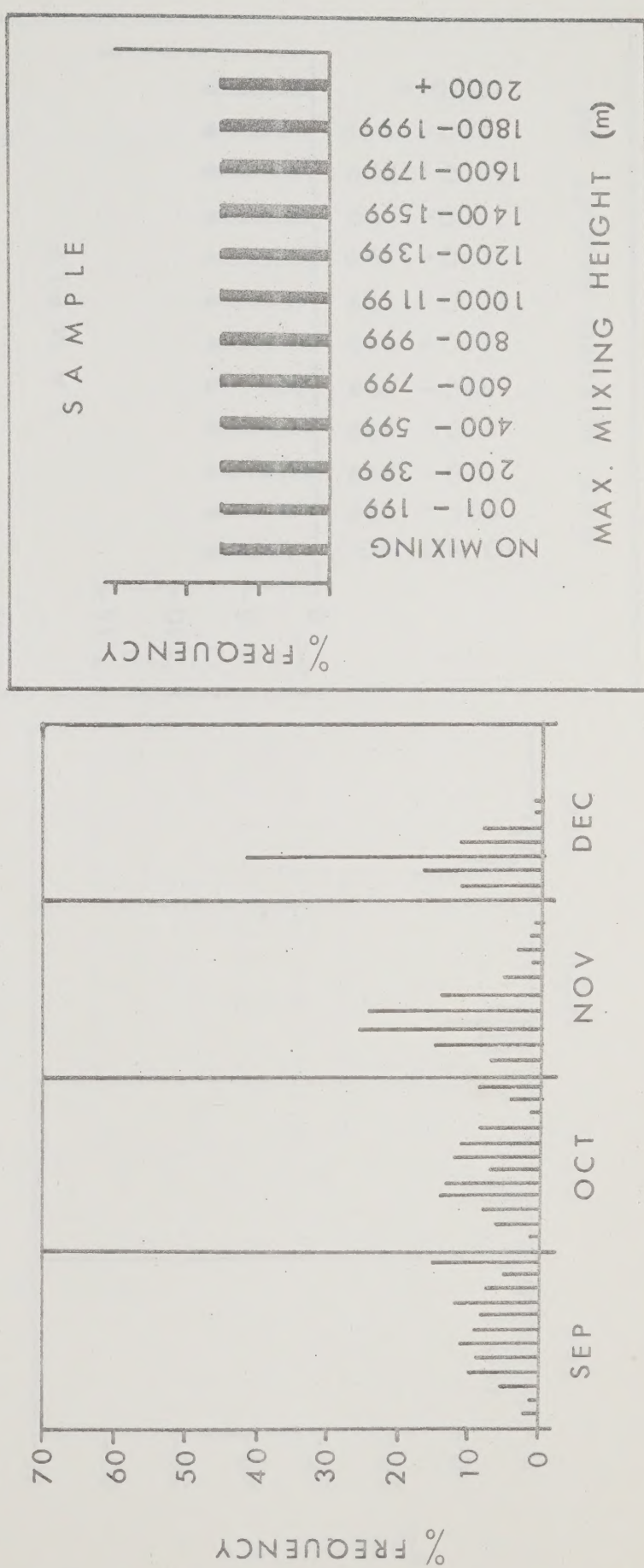
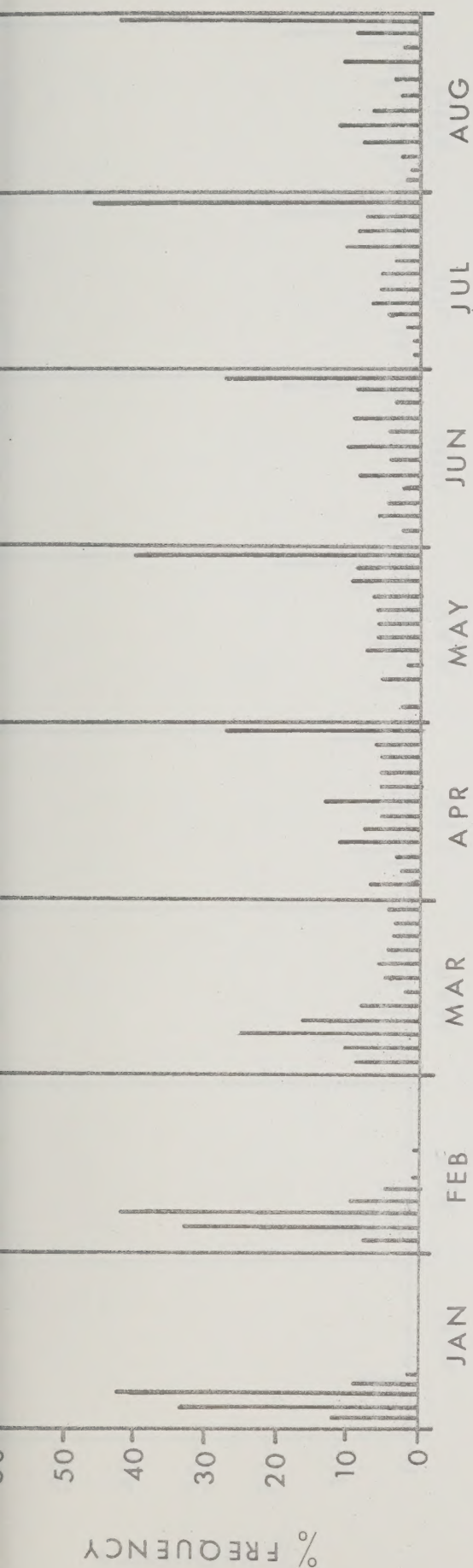


FIG. 8 FREQUENCIES OF OCCURRENCE OF SPECIFIED MAX. MIXING HEIGHTS AT GLASGOW, MONTANA
(JULY 1965 - JUNE 1969 ALL WIND DIRECTIONS)

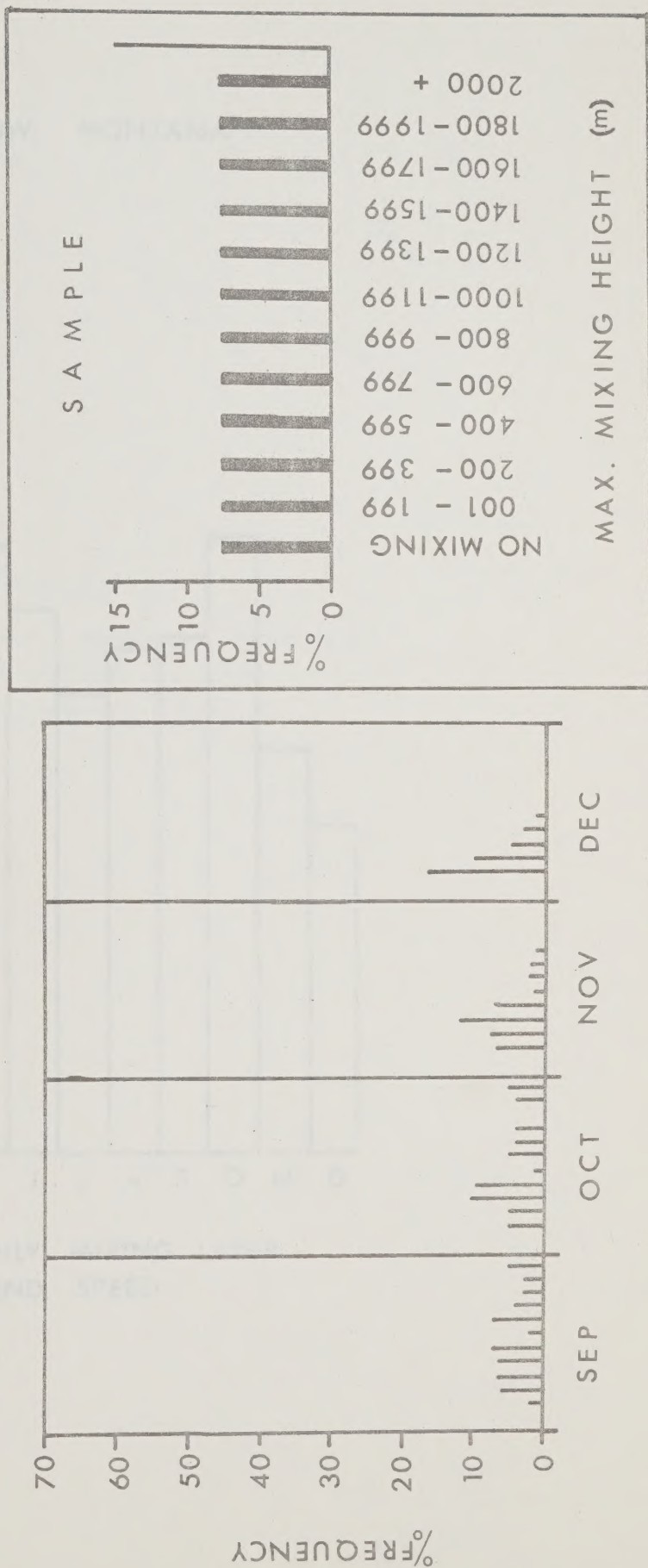
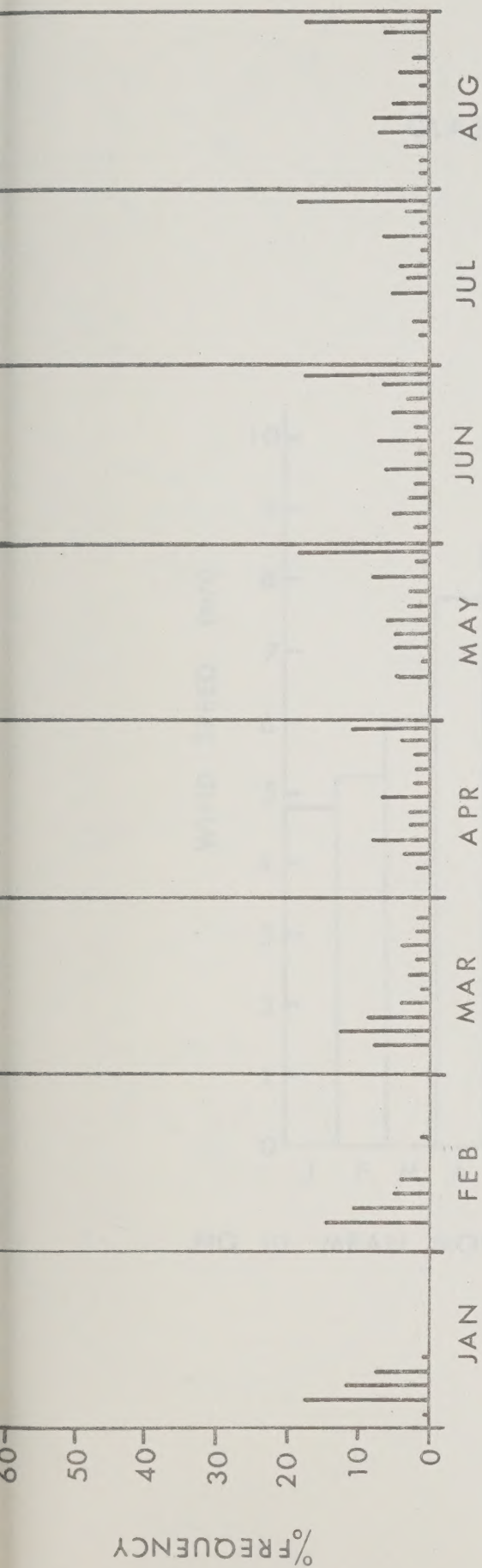


FIG. 9 FREQUENCIES OF OCCURRENCE OF SPECIFIED MAX. MIXING HEIGHTS AT GLASGOW, MONTANA

(JULY 1965 - JUNE 1969 WINDS FROM $290^{\circ} - 080^{\circ}$)

GLASGOW, MONTANA

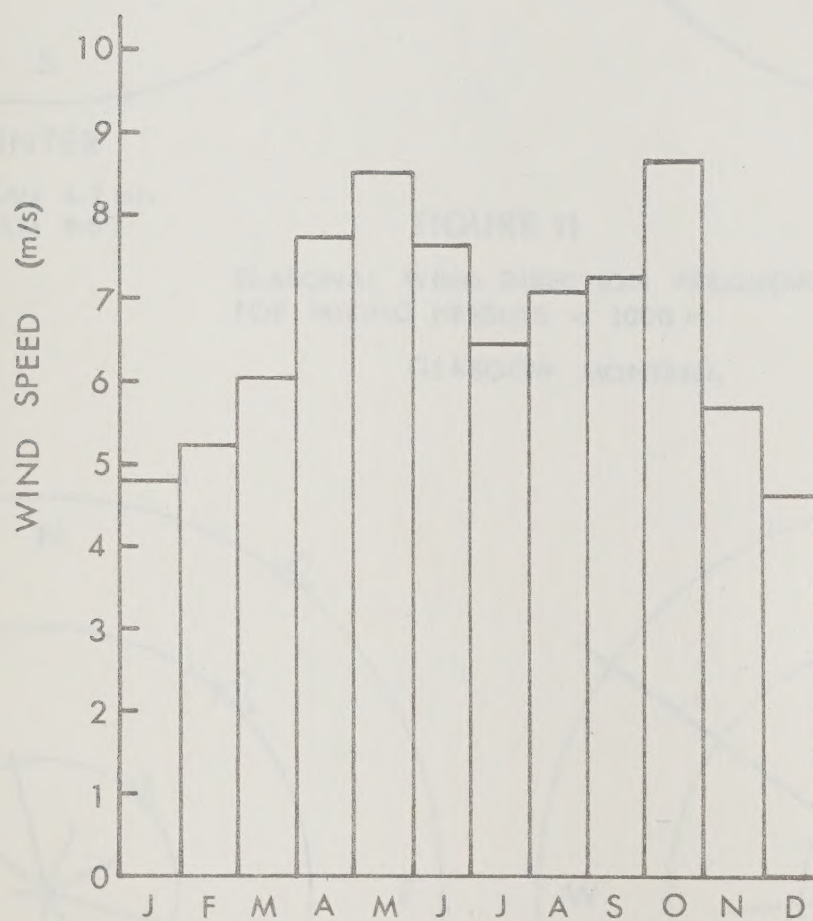


FIG. 10 MEAN MONTHLY MIXING LAYER
WIND SPEED

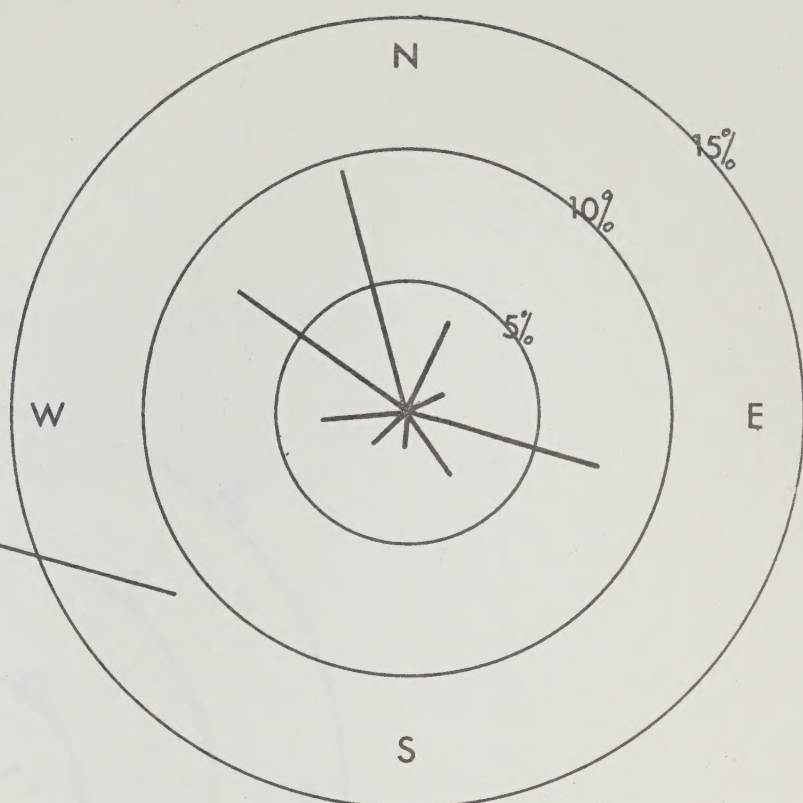
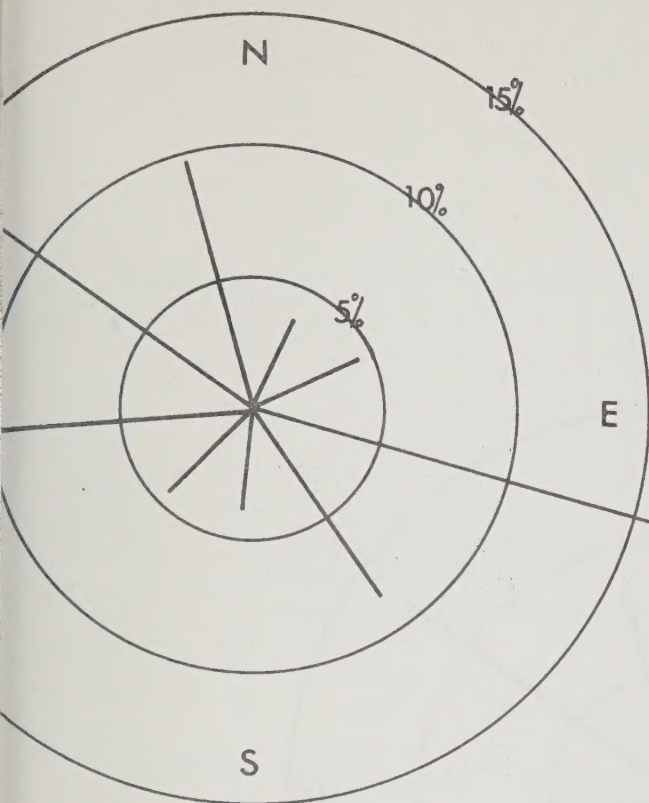
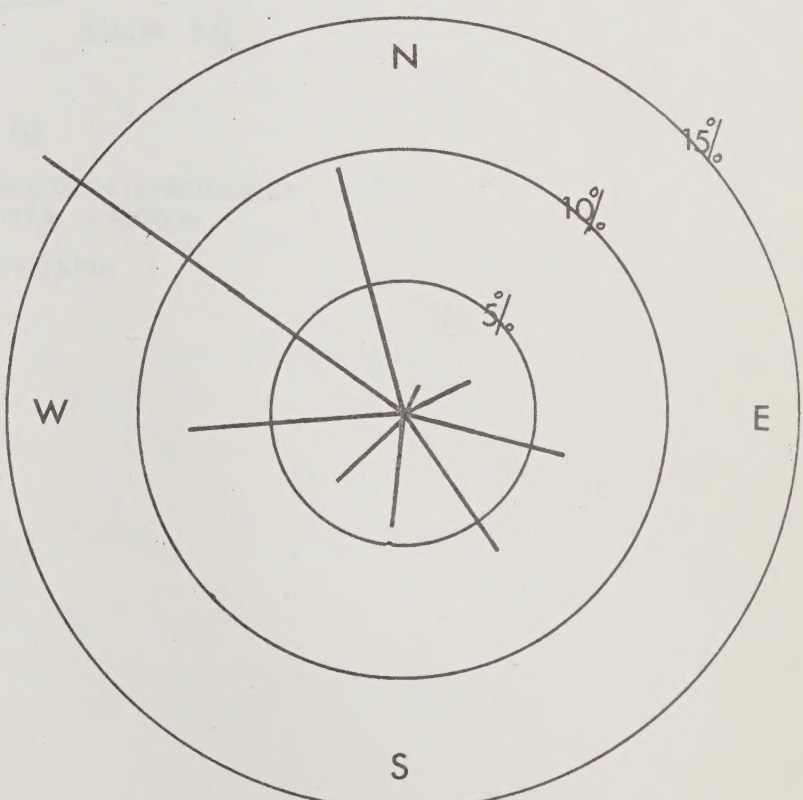
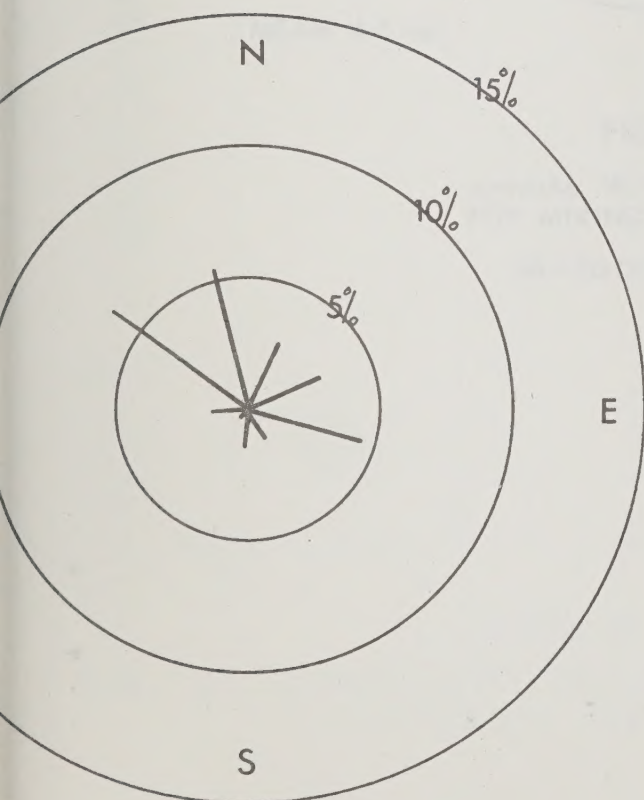


FIGURE 11

SEASONAL WIND DIRECTION FREQUENCY
FOR MIXING HEIGHTS < 1000 m

GLASGOW, MONTANA



SUMMER
MEAN 7.1 m/s
CALM 0.0 %

AUTUMN
MEAN 7.2 m/s
CALM 1.5 %

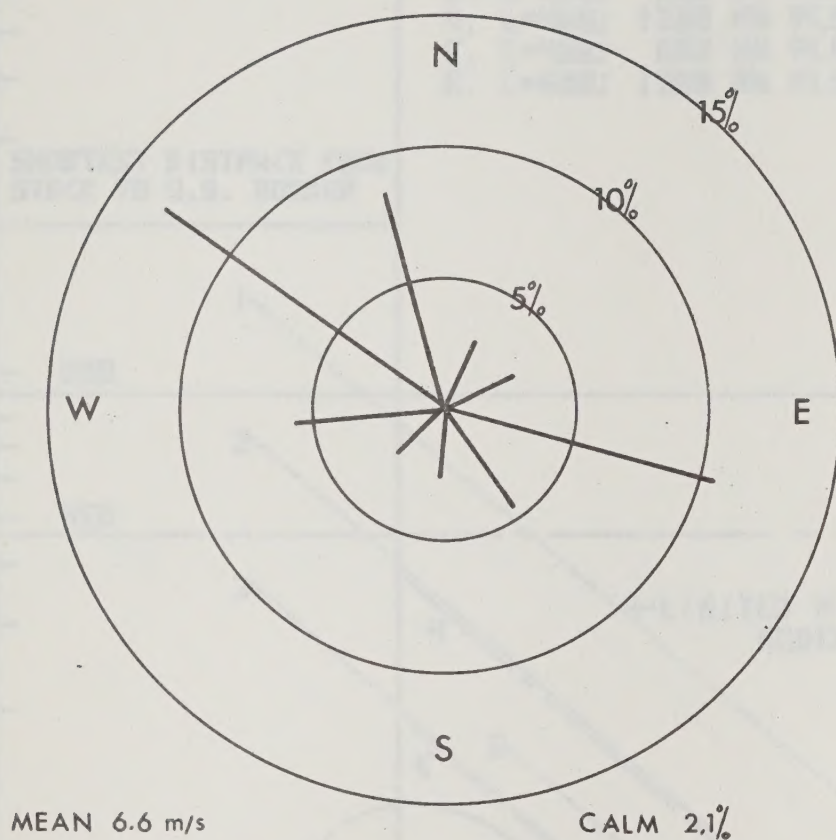


FIGURE 12

ANNUAL WIND DIRECTION FREQUENCY
FOR MIXING HEIGHTS < 1000 m

GLASGOW, MONTANA

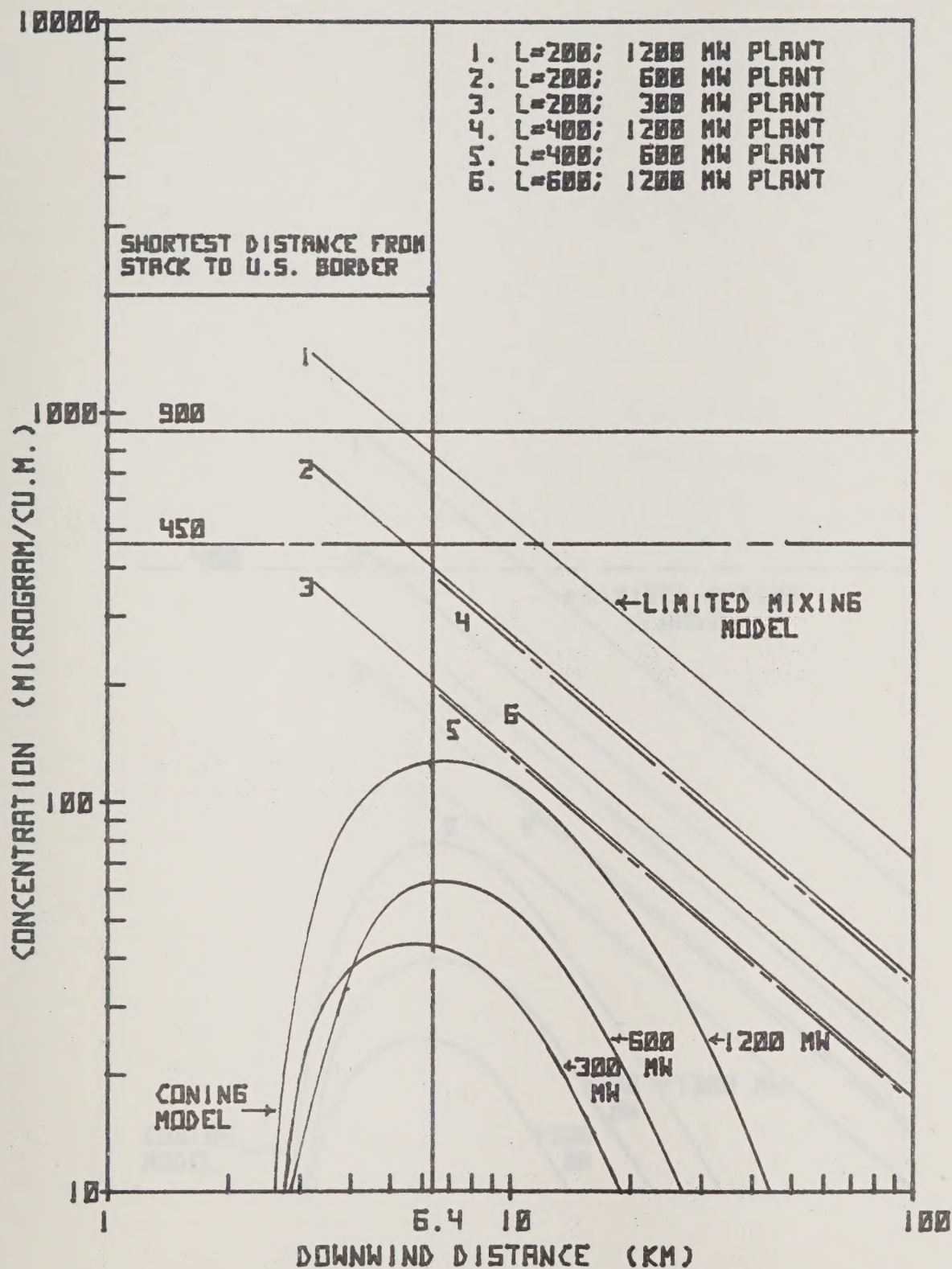


FIG. 13 GROUND-LEVEL ONE-HOUR SO_2 CONCENTRATION ALONG PLUME CENTRELINE FOR STABILITY CLASS C AND $U=5$ M/S

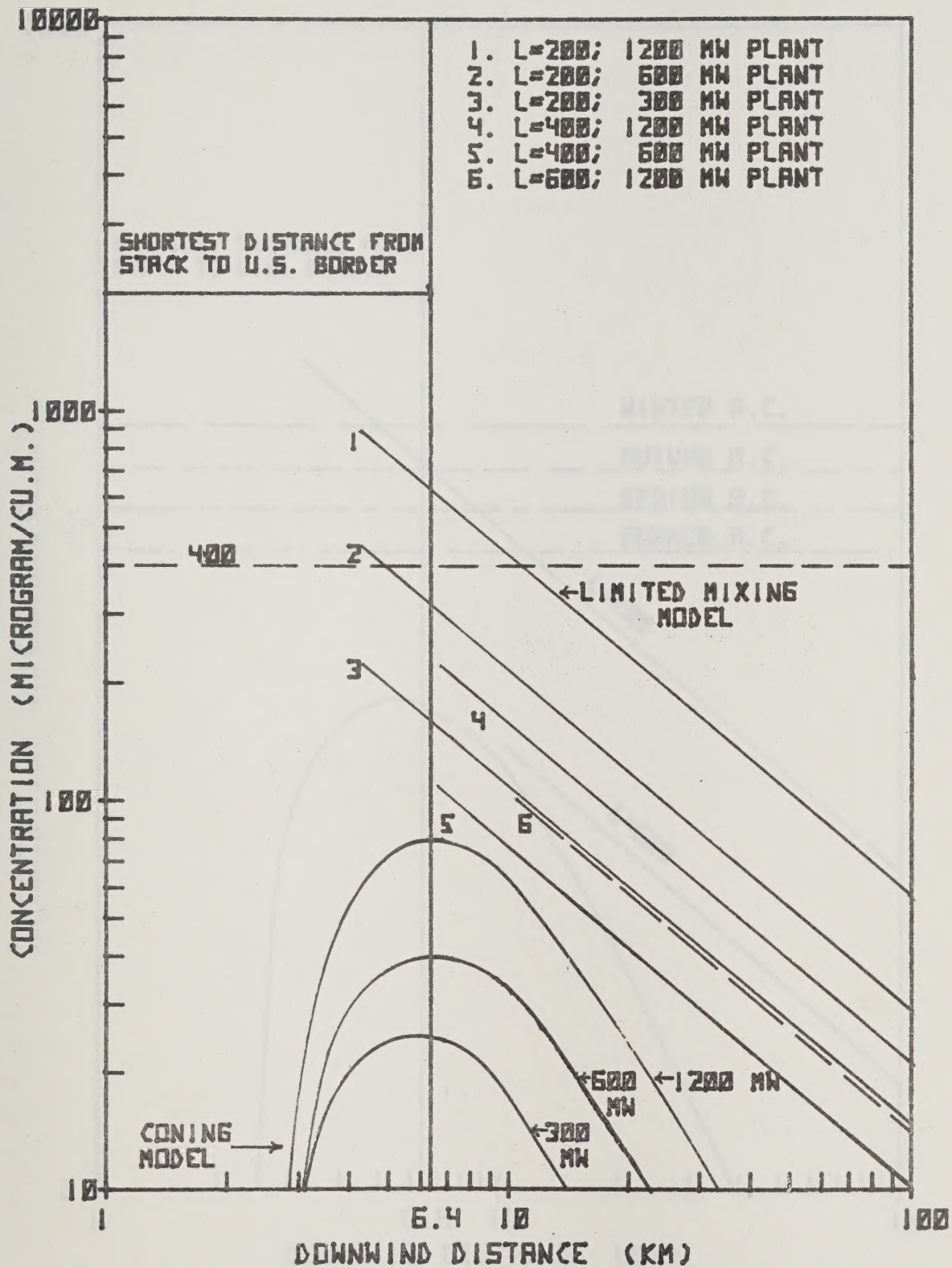


FIG. 14 GROUND-LEVEL ONE-HOUR NO_2 CONCENTRATION ALONG PLUME CENTRELINE FOR STABILITY CLASS C AND $U=5$ M/S

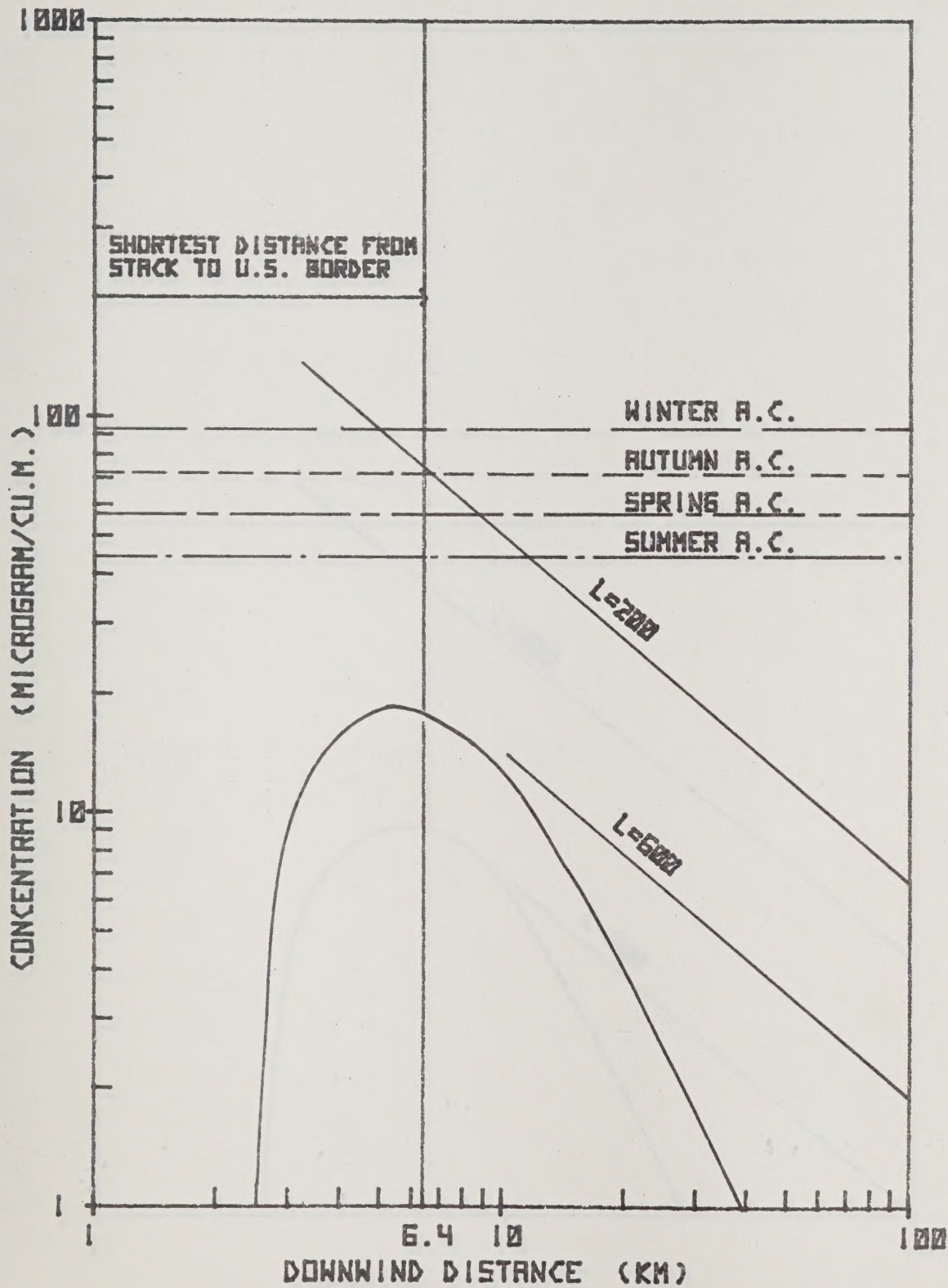


FIG. 15(A) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE
CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 1: 300 MW PLANT 96.0 % E.S.P. EFFICIENCY

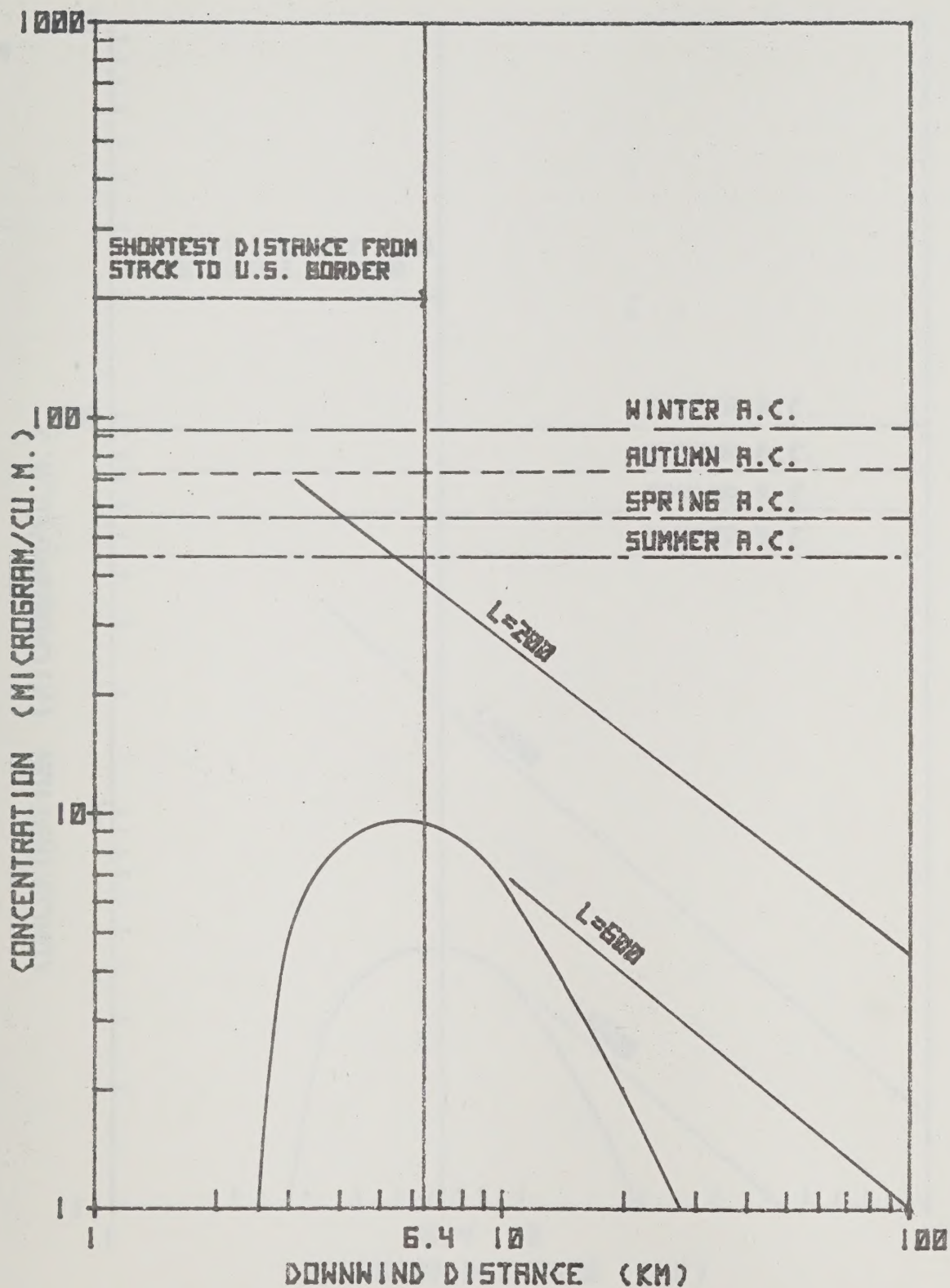


FIG. 15(B) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE
CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 2; 300 MW PLANT 98.0 % E.S.P. EFFICIENCY

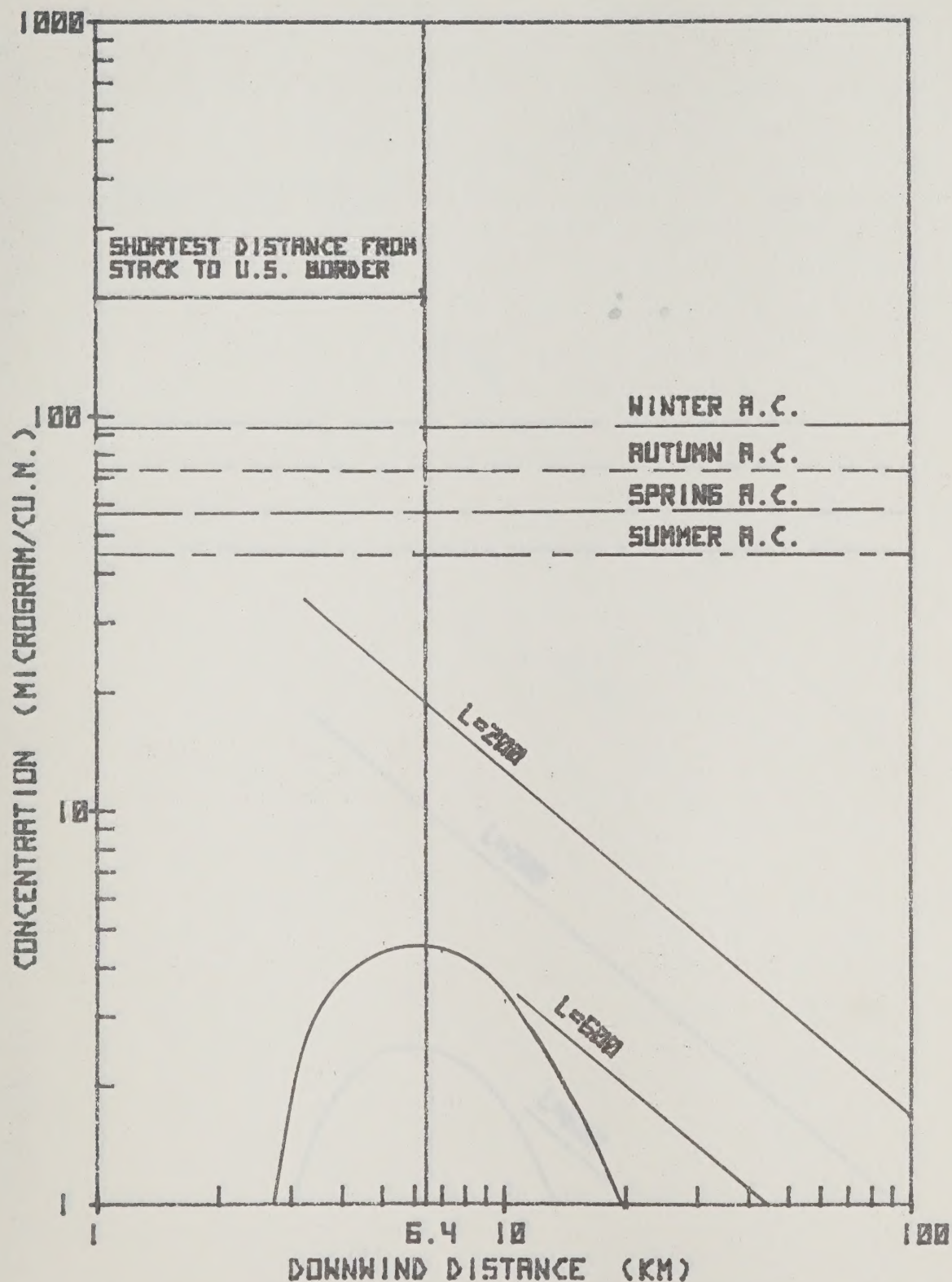


FIG. 15(C) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE
CONCENTRATION FOR STABILITY CLASS C AND U=5 M/S

CASE 3; 300 MW PLANT 99.0 % E.S.P. EFFICIENCY

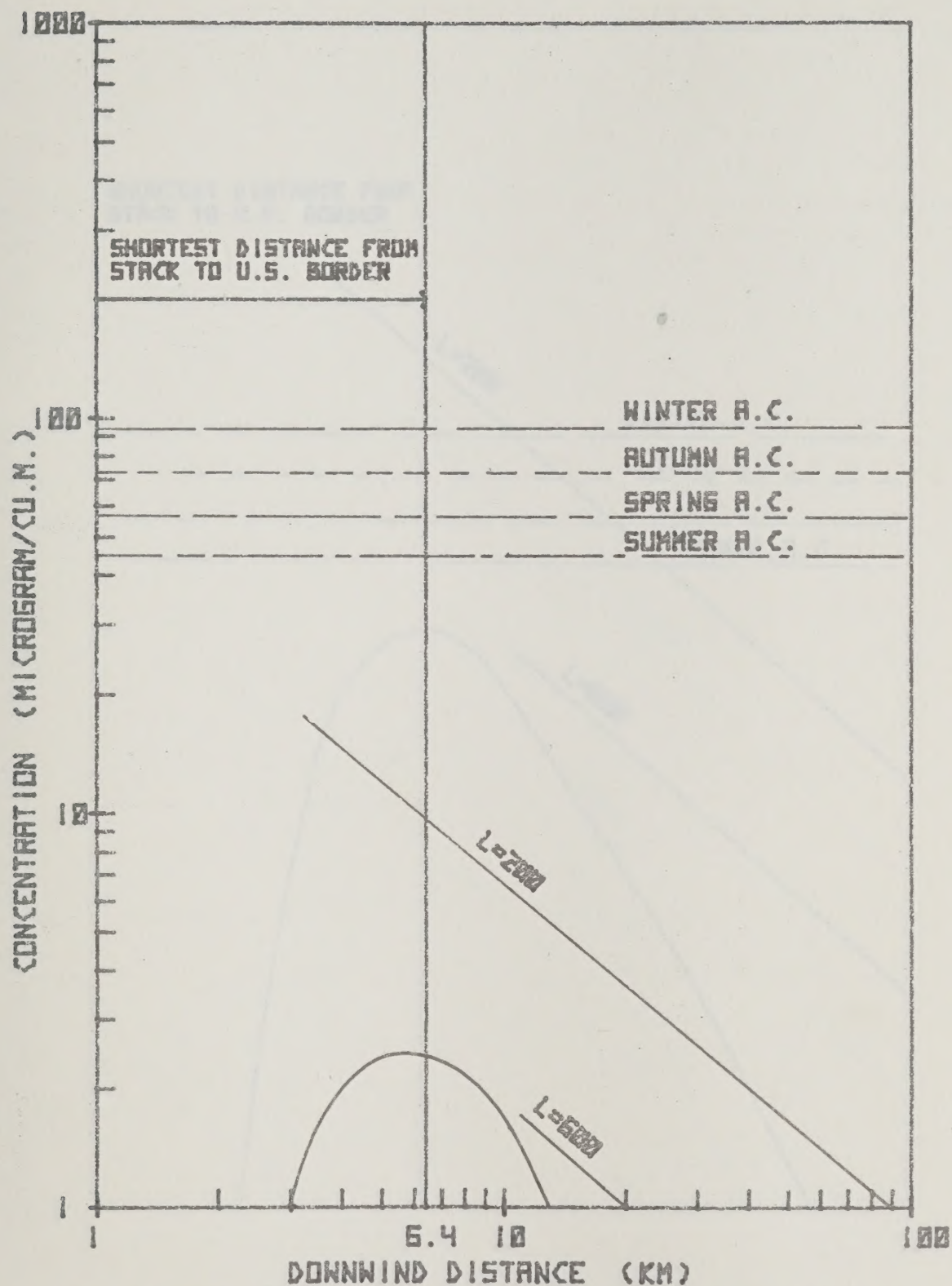


FIG. 15(D) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 4: 300 MW PLANT 99.5 % E.S.P. EFFICIENCY

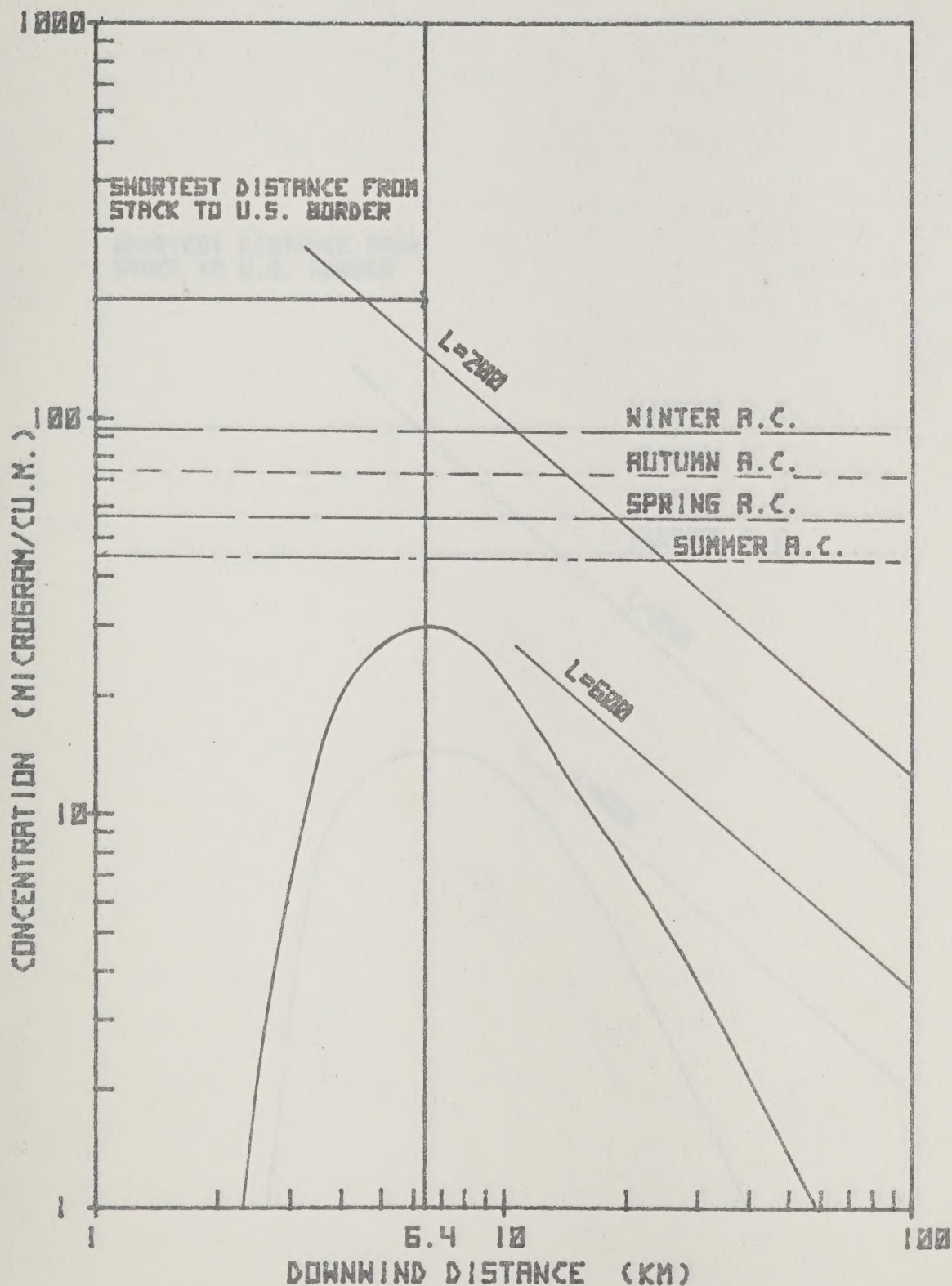


FIG. 15(E) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 5; 600 MW PLANT 96.0 % E.S.P. EFFICIENCY
AND 1200 MW PLANT 98.0 % E.S.P. EFFICIENCY

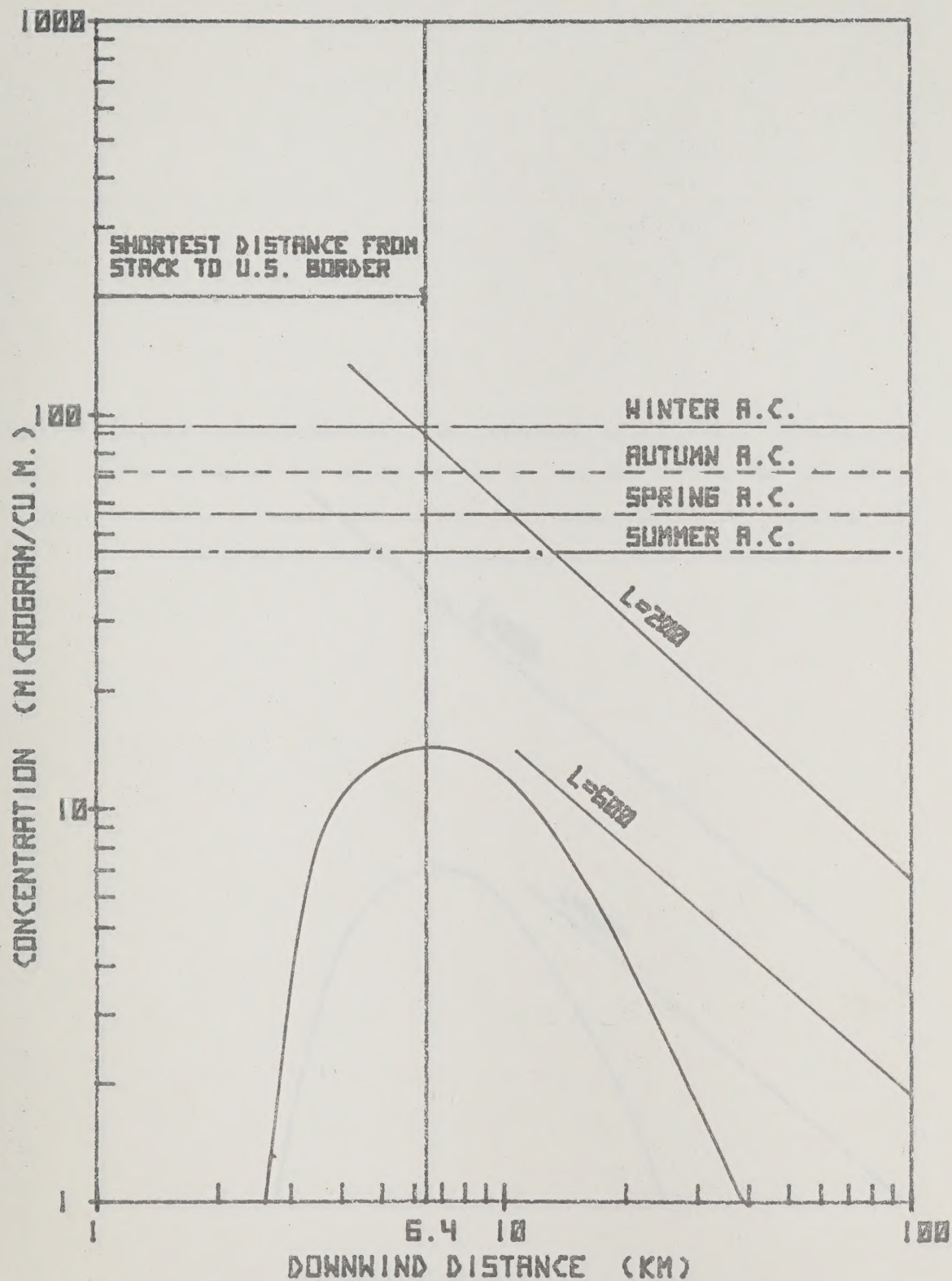


FIG. 15(F) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 6; 600 MW PLANT 98.0 % E.S.P. EFFICIENCY
AND 1200 MW PLANT 99.0 % E.S.P. EFFICIENCY

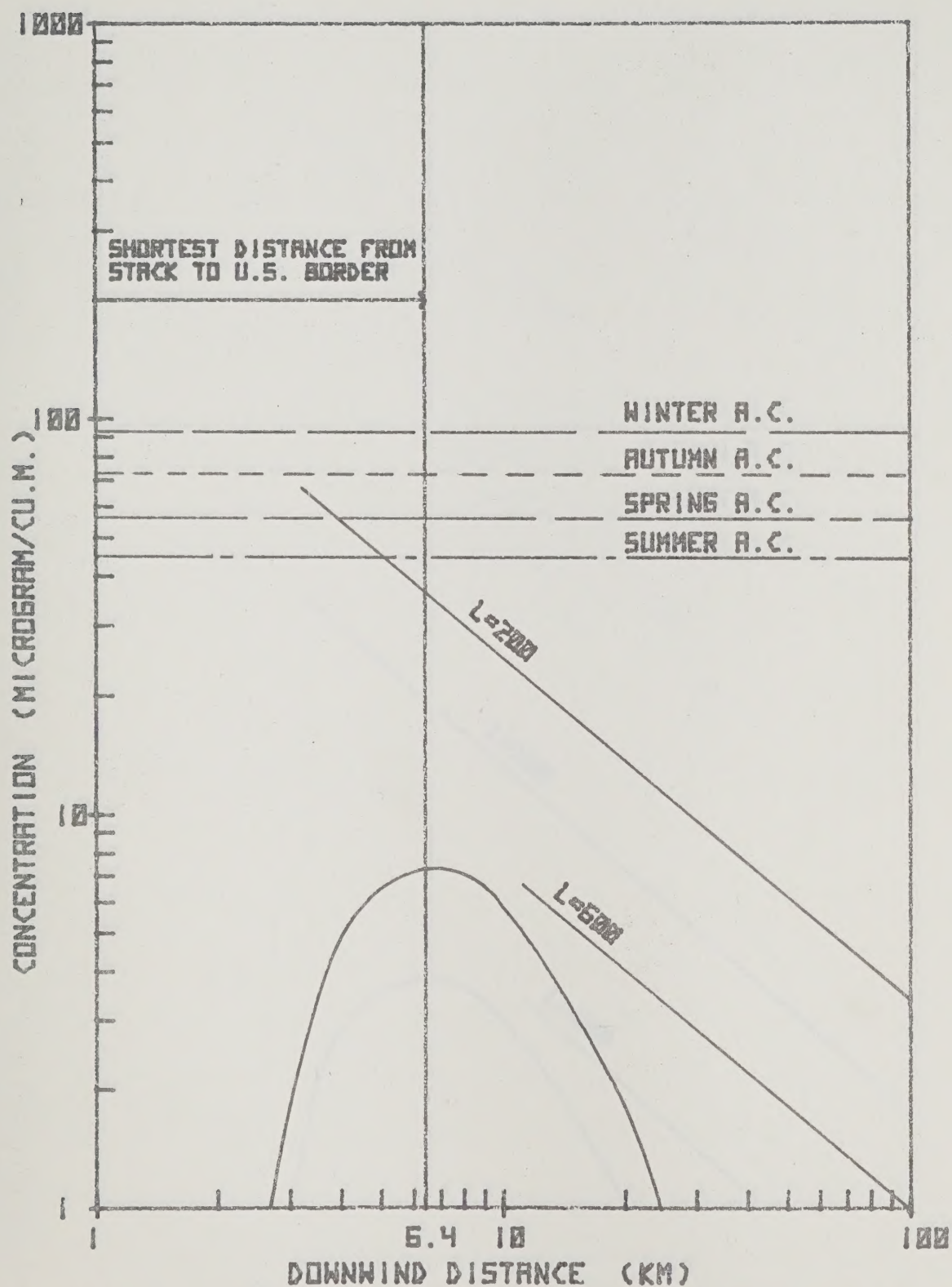


FIG. 15(G) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 7; 600 MW PLANT 99.0 % E.S.P. EFFICIENCY
AND 1200 MW PLANT 99.5 % E.S.P. EFFICIENCY

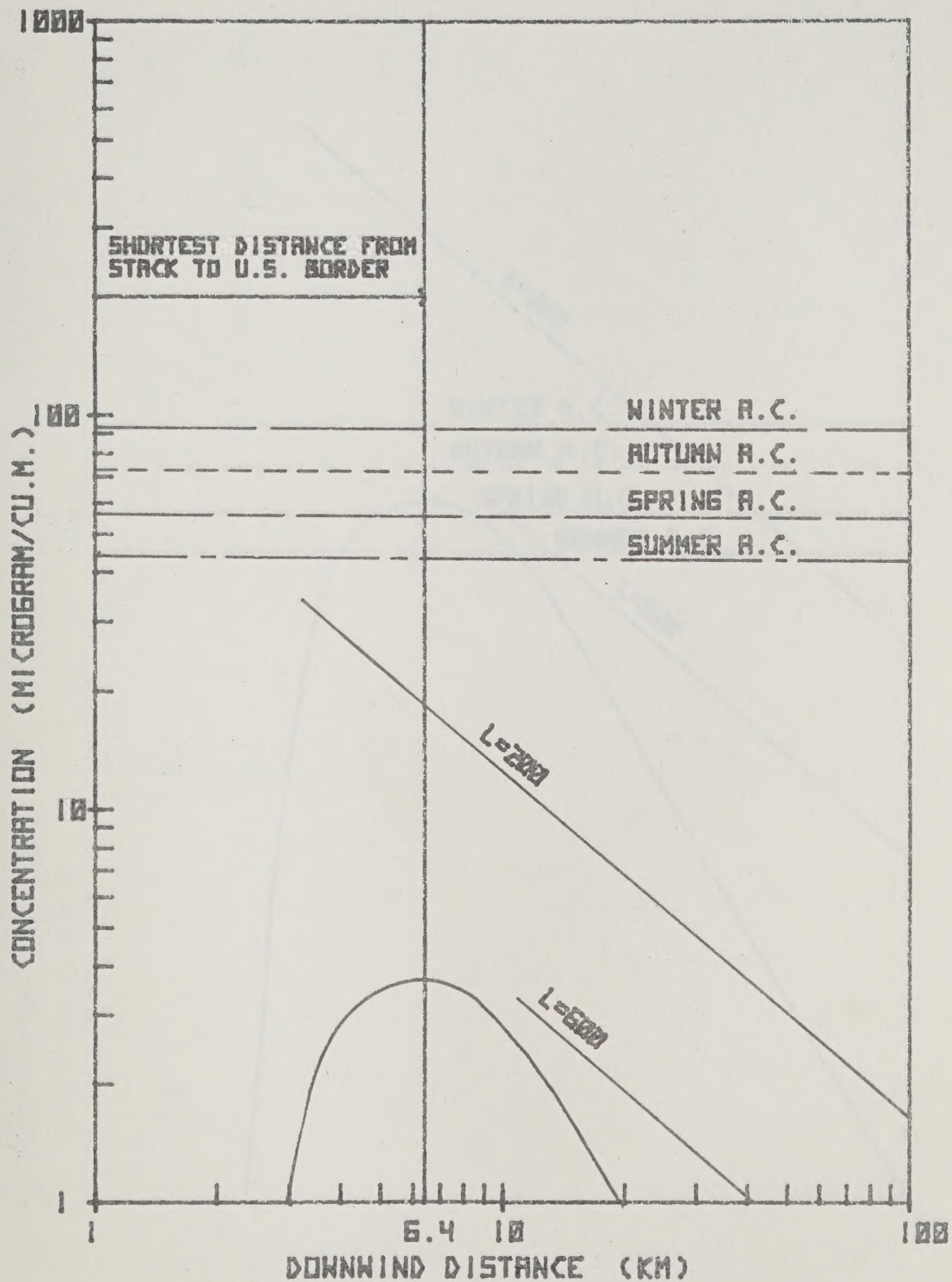


FIG. 15(H) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE
CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE B; 600 MW PLANT 99.5 % E.S.P. EFFICIENCY

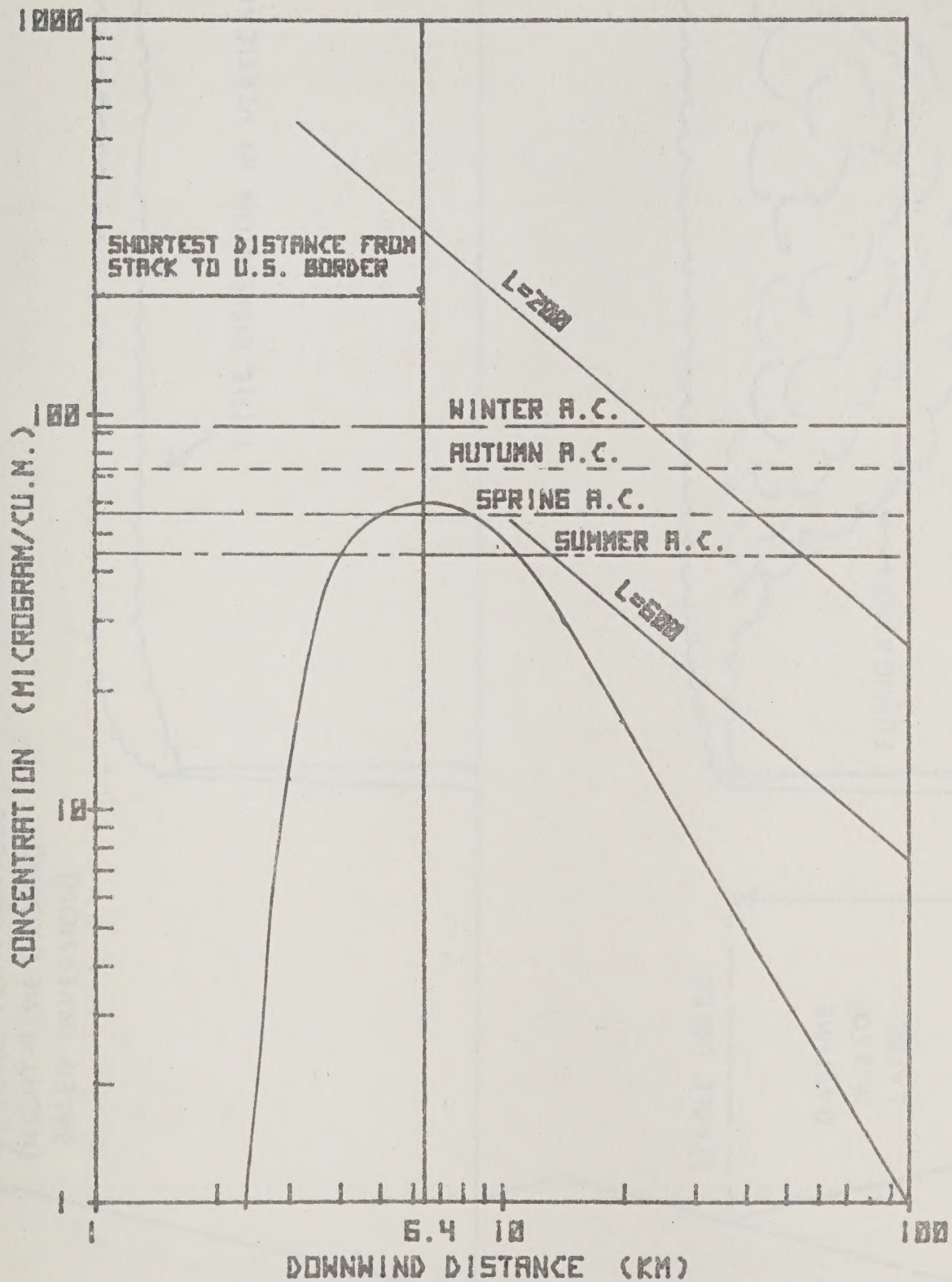


FIG. 15(1) GROUND-LEVEL 24-HOUR SUSPENDED PARTICULATE CONCENTRATION FOR STABILITY CLASS C AND $U=5$ M/S

CASE 9; 1200 MW PLANT 96.0 % E.S.P. EFFICIENCY

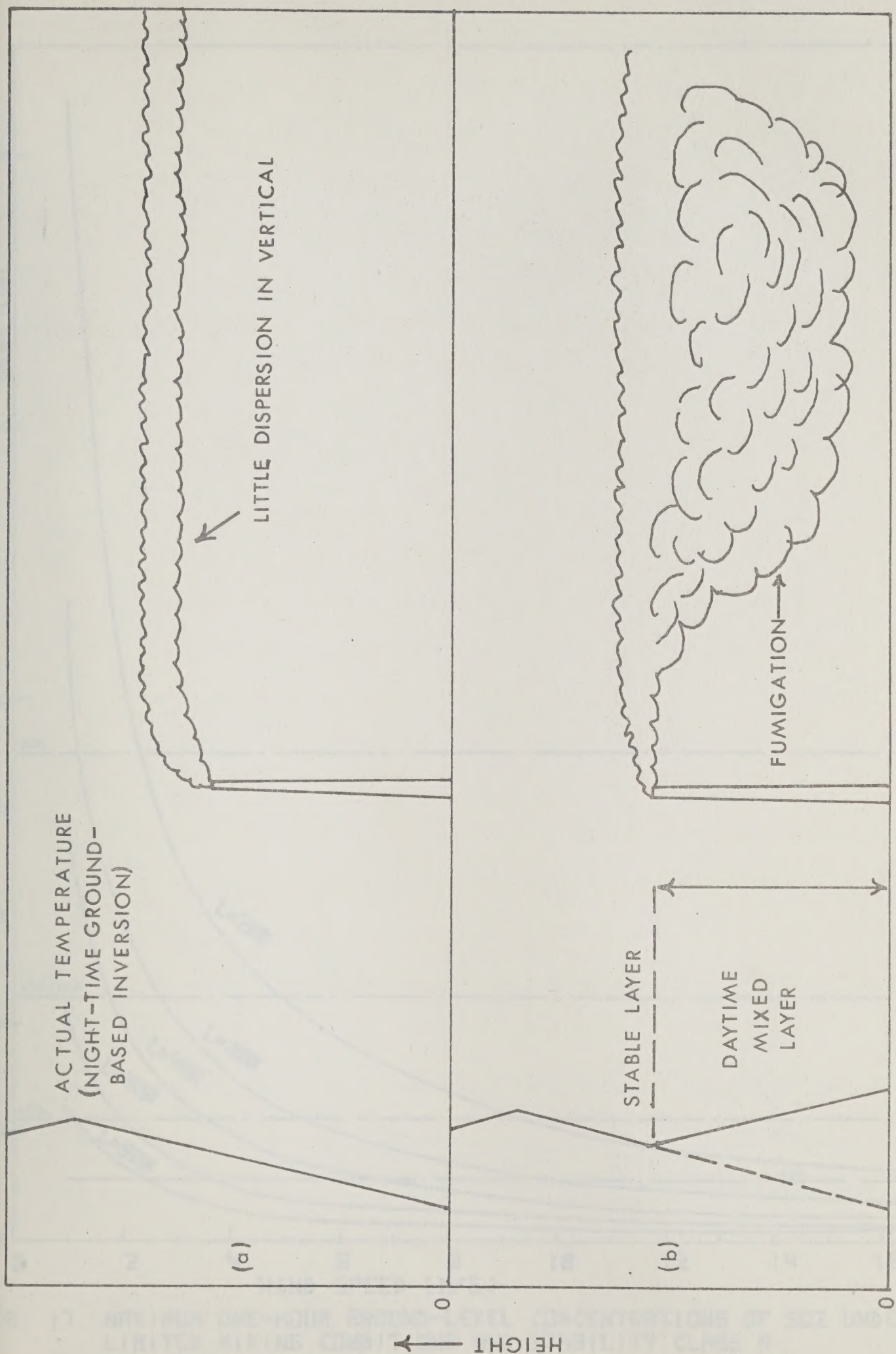


FIGURE 16 PICTORIAL VIEW of: (a) PLUME DISPERSION AT NIGHT

(b) MORNING FUMIGATION

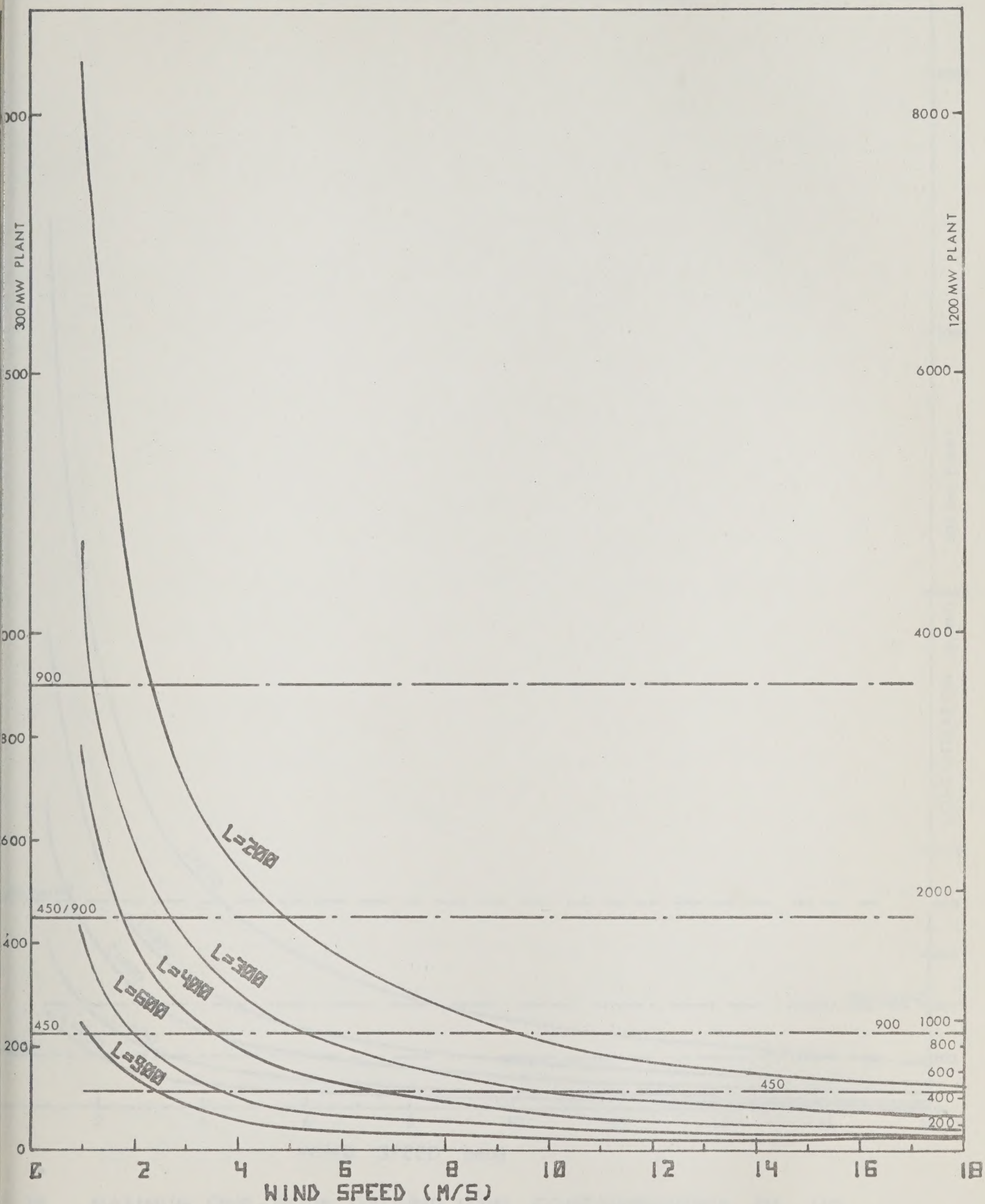


FIG. 17 MAXIMUM ONE-HOUR GROUND-LEVEL CONCENTRATIONS OF SO₂ UNDER LIMITED MIXING CONDITIONS AND STABILITY CLASS A

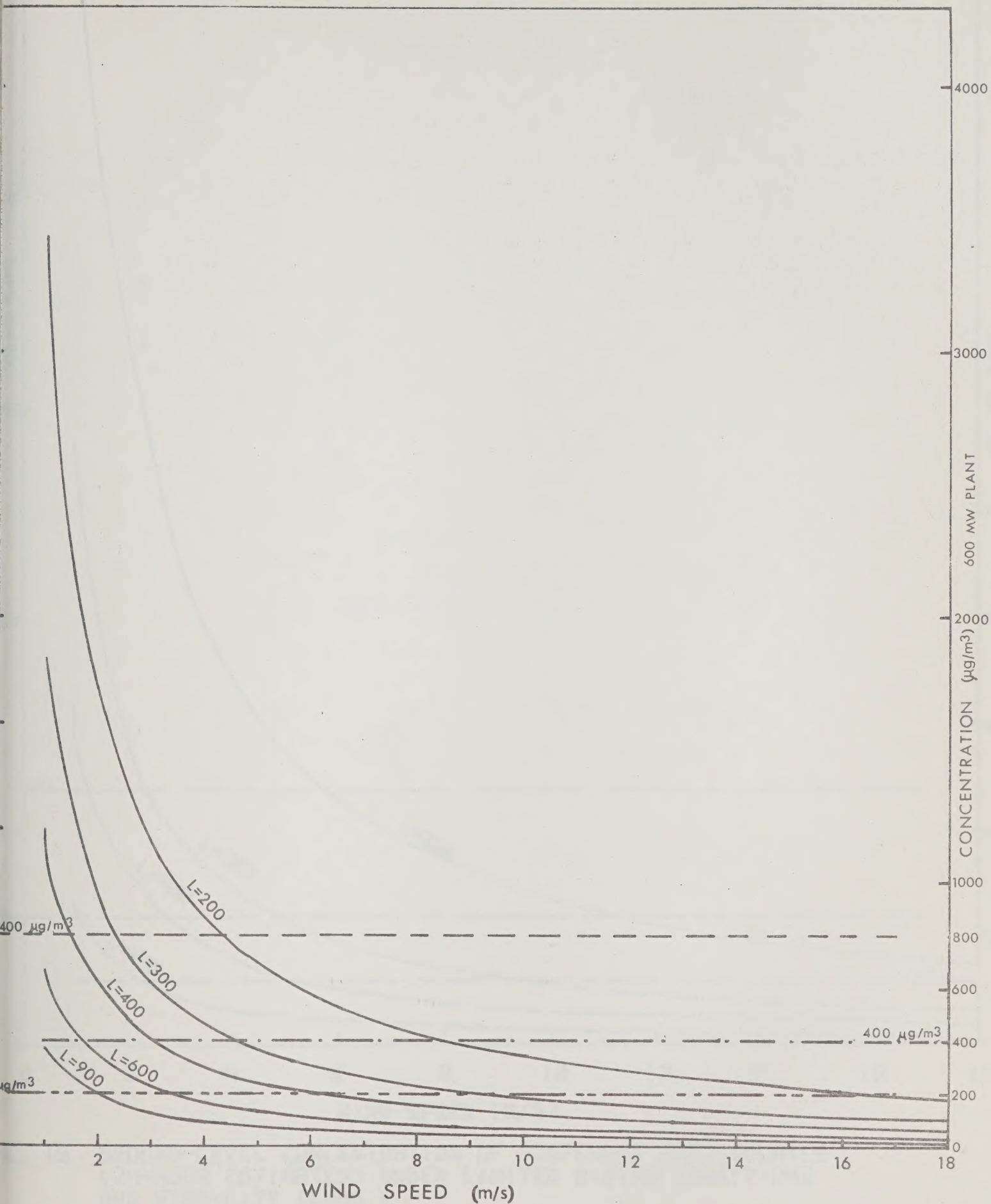
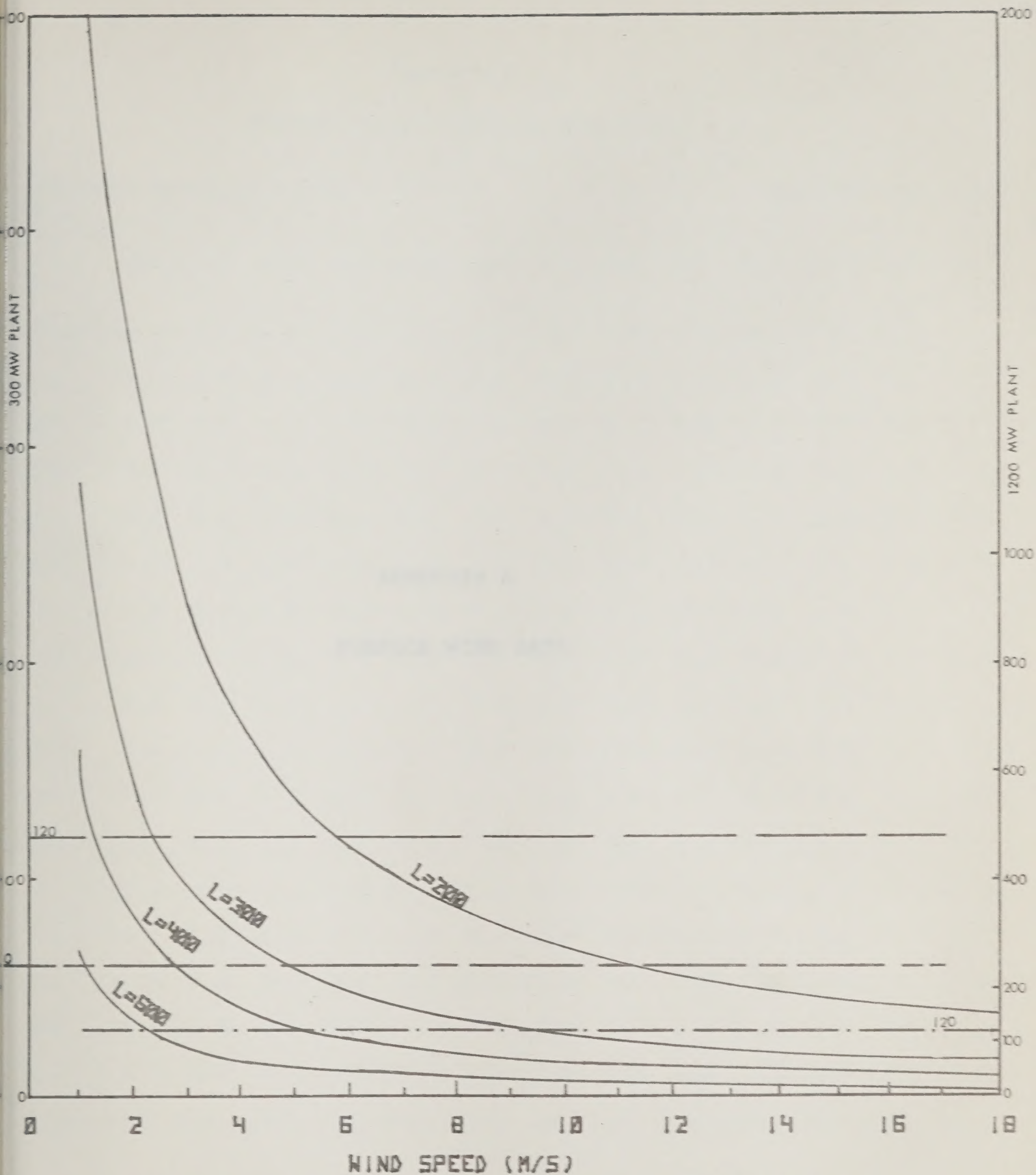


FIGURE 18 MAXIMUM ONE-HOUR GROUND LEVEL CONCENTRATIONS OF NO₂ UNDER LIMITED MIXING CONDITIONS AND STABILITY CLASS A



6. 19 GROUND-LEVEL CONCENTRATION OF SUSPENDED PARTICULATES (24-HOUR ESTIMATES) UNDER LIMITED MIXING CONDITIONS AND STABILITY CLASS C

TABLE A-1

MONTHLY WIND DIRECTION FREQUENCY
(%)

STATION: ROSELIN 1947-1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
FROM	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
040	1.9	2.5	3.0	4.4	6.7	2.4	0.7	5.0	1.4	8.6	1.3	2.3	2.8
080	0.7	1.2	1.0	2.5	1.9	1.5	2.9	2.4	2.2	2.7	0.2	4.3	1.9
120	0.5	2.1	1.3	1.9	2.5	1.1	2.4	2.8	2.2	1.1	1.1	6.8	2.1
160	1.2	3.0	2.3	1.0	0.0	3.0	0.5	0.2	2.3	2.4	2.0	2.3	2.0
200	1.0	4.4	2.4	1.0	0.0	3.0	0.5	0.2	2.3	2.4	2.0	2.3	2.0
240	1.5	4.8	3.9	1.1	0.0	2.0	0.0	0.3	2.1	2.2	2.4	2.1	2.1
280	4.7	7.7	10.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
320	5.9	6.0	8.8	6.3	8.1	7.4	4.4	1.7	4.7	2.7	2.8	2.8	7.2
360	5.0	5.0	6.2	4.9	2.8	4.0	2.9	7.3	5.4	5.4	4.3	7.3	5.0
010	7.5	5.6	7.7	9.0	5.9	4.1	4.3	7.3	4.3	4.3	3.2	9.7	7.2
050	13.3	12.2	7.0	6.2	3.9	3.3	0.4	3.4	3.3	12.2	7.3	11.4	7.3
090	12.4	13.7	8.7	4.9	4.2	11.1	3.7	4.3	11.4	8.2	10.4	11.1	9.0
130	18.3	9.0	6.3	7.4	6.2	9.5	12.7	5.9	12.2	7.2	9.1	13.1	8.2
170	11.3	7.3	8.1	9.7	4.3	10.4	11.0	5.4	9.3	3.8	10.2	12.3	7.2
210	15.5	11.7	9.7	9.3	7.3	7.4	10.7	9.3	4.5	17.6	5.4	7.0	11.2
250	1.7	0.0	3.7	2.1	4.3	3.1	5.9	0.0	7.3	2.3	3.2	4.3	3.2
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

APPENDIX A

SURFACE WIND DATA

MONTHLY WIND DIRECTION FREQUENCY
(%)

PERIOD: 1971-1973

[illegible]

MONTHLY WIND DIRECTION FREQUENCY
(%)

PERIOD: 1964-1973

[illegible]

MONTHLY WIND DIRECTION FREQUENCY
(%)

PERIOD: 1957-1966

[illegible]

(%)

STATION: REGINA A SASK.

PERIOD: 1957-1966

[illegible]

TABLE A.5

STATION: ESTEVAN A SASK.

PERIOD: 1964-1973

[illegible]

TABLE A.6

MEAN MONTHLY WIND SPEED
BY DIRECTION
(M/S)

STATION: ROCKGLEN SASK.

PERIOD: 1971-1973

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
NNE	3.6	3.8	5.5	4.3	4.6	5.5	4.1	3.8	5.6	4.6	3.5	4.6	4.4
NE	2.0	3.8	2.4	3.7	3.4	3.1	2.5	2.9	3.3	3.9	3.8	4.5	3.3
ENE	3.5	4.1	8.0	4.0	4.1	3.4	3.2	4.3	4.6	2.7	2.7	2.8	4.0
E	3.0	4.6	5.1	4.8	4.5	4.9	3.9	4.2	4.6	4.6	4.2	5.0	4.4
ESE	3.8	4.6	5.9	4.5	5.1	5.0	4.0	4.6	5.5	4.1	4.9	5.2	4.8
SE	4.6	5.1	7.2	7.6	4.4	6.2	5.6	5.3	6.5	5.9	4.3	5.3	5.7
SSE	5.4	6.3	7.3	7.2	6.1	6.4	5.7	5.7	6.3	6.5	6.2	6.1	6.3
S	5.9	5.9	6.0	5.1	5.3	5.6	5.1	4.9	5.3	6.7	5.0	6.1	5.6
SSW	6.2	6.0	5.7	5.9	5.5	5.7	4.6	5.2	5.2	6.8	5.6	6.2	5.7
SW	5.9	5.9	5.5	5.4	5.3	5.2	4.5	5.1	6.1	6.4	5.5	6.0	5.6
WSW	7.6	7.2	6.0	6.6	5.8	5.9	5.3	5.6	6.2	7.0	5.9	6.9	6.3
W	7.7	6.8	6.0	7.1	6.2	5.9	6.1	4.9	6.3	6.9	6.6	6.2	6.4
WNW	7.2	7.0	6.7	8.4	6.5	6.5	6.6	6.0	7.5	6.3	8.4	6.0	6.9
NW	7.4	7.2	6.6	6.7	5.6	5.6	5.5	5.9	5.9	7.1	6.9	6.6	6.4
NNW	7.0	7.1	6.0	6.8	6.1	6.6	5.0	6.3	5.2	7.2	5.1	6.4	6.2
N	5.9	5.0	5.9	5.9	5.0	4.1	3.9	4.5	5.5	5.7	5.3	5.1	5.1
AVG	6.6	6.2	6.3	6.1	5.3	5.7	5.1	5.1	5.9	6.3	5.8	6.0	5.9

TABLE A.7
MEAN MONTHLY WIND SPEED
BY DIRECTION
(M/S)

STATION: SWIFT CURRENT A SASK.

PERIOD: 1964-1973

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
NNE	4.9	5.9	6.7	8.1	6.3	7.1	4.6	5.1	6.1	5.2	5.0	4.6	5.8
NE	5.1	5.2	6.3	6.9	6.1	6.8	4.7	5.5	6.3	5.5	4.1	5.6	5.7
ENE	5.8	5.2	5.9	7.4	7.1	5.7	5.0	5.2	6.1	5.4	5.0	6.1	5.8
E	5.2	5.4	6.1	6.6	6.3	6.0	5.4	5.2	5.4	5.5	5.6	6.1	5.7
ESE	7.0	6.9	7.1	6.9	6.8	6.6	6.2	5.9	5.8	6.6	6.6	6.8	6.6
SE	6.9	6.9	6.6	7.0	7.3	6.9	5.7	6.1	6.1	6.0	5.8	6.9	6.5
SSE	7.7	6.7	6.9	7.6	7.6	6.9	6.0	6.3	6.5	7.0	6.6	7.3	6.9
S	8.6	8.3	7.3	7.3	6.9	6.4	6.3	6.1	6.5	7.4	7.3	7.6	7.2
SSW	8.4	8.5	7.3	7.6	6.6	6.4	5.9	6.3	6.7	7.2	7.4	8.1	7.2
SW	7.4	7.9	6.9	6.5	6.7	6.3	5.6	5.7	6.1	6.9	6.9	7.3	6.7
WSW	7.4	7.6	6.5	6.9	7.2	6.7	6.3	6.5	6.5	6.9	6.4	7.3	6.8
W	7.9	8.0	7.2	7.3	7.1	7.0	6.6	7.1	7.0	7.2	7.2	7.6	7.3
WNW	8.9	8.9	7.8	8.0	7.9	7.8	7.3	7.6	8.3	8.2	8.2	8.9	8.2
NW	7.8	9.0	7.7	7.2	7.8	6.9	6.5	6.9	7.8	8.0	8.0	8.0	7.6
NNW	6.4	9.5	7.4	7.2	7.6	6.4	5.9	6.1	7.1	7.3	6.8	7.3	7.1
N	5.4	7.5	6.5	6.9	7.0	5.4	4.9	4.7	5.6	5.8	5.2	5.3	5.8
AVG	7.5	7.8	6.9	7.1	7.0	6.5	5.9	6.1	6.5	7.1	6.8	7.5	6.9

TABLE A.8

MEAN MONTHLY WIND SPEED
BY DIRECTION
(M/S)

STATION: ESTEVAN A GASK.

PERIOD: 1964-1973

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
NNE	3.4	3.5	4.3	4.4	4.5	4.5	3.3	4.0	4.5	4.1	3.4	2.8	3.9
NE	2.9	3.2	3.8	5.6	4.0	4.1	3.1	3.6	4.3	4.1	3.2	2.9	3.7
ENE	4.0	4.3	4.5	5.7	5.3	4.8	4.1	4.4	4.9	4.6	4.3	4.3	4.6
E	5.4	5.5	4.9	5.7	5.6	4.9	4.9	4.4	4.5	4.8	4.9	5.3	5.1
ESE	6.4	6.1	5.9	5.9	6.1	5.7	5.7	5.5	6.1	5.3	5.3	5.6	5.8
SE	4.6	4.6	5.6	6.1	6.5	6.0	5.2	5.6	5.5	4.8	4.9	5.6	5.4
SSE	4.8	4.3	5.3	5.9	6.2	5.6	5.3	5.5	5.9	5.2	5.1	4.7	5.3
S	4.3	4.1	4.9	5.4	5.7	5.1	4.8	4.9	5.5	4.9	4.6	4.5	4.9
SSW	5.1	5.3	4.8	5.3	5.2	5.0	4.6	4.7	5.2	5.4	5.3	5.4	5.1
SW	6.1	6.1	5.1	5.5	5.1	4.4	4.5	4.2	5.0	5.4	5.5	5.6	5.2
WSW	5.5	5.7	4.9	5.5	5.6	4.8	5.1	4.2	5.2	5.3	5.0	5.4	5.2
W	5.4	5.3	4.7	6.0	5.9	5.5	5.7	5.5	5.4	5.3	5.3	5.5	5.5
WNW	7.3	7.0	6.3	6.9	6.8	6.4	6.3	6.1	6.6	6.8	6.8	7.1	6.7
NW	7.7	7.9	6.7	6.6	6.9	6.2	6.0	6.0	6.7	7.6	7.0	7.5	6.9
NNW	6.0	6.7	6.2	5.7	6.3	5.5	5.4	5.2	6.1	6.2	5.8	5.1	5.9
N	3.7	4.5	5.3	5.1	5.8	5.1	4.2	4.4	4.8	4.8	4.2	2.9	4.5
AVG	5.9	5.9	5.5	5.8	5.9	5.3	5.1	5.0	5.5	5.7	5.5	5.6	5.6

TABLE A.9

MEAN MONTHLY WIND SPEED
BY DIRECTION
(M/S)

STATION: REGINA A SASK.

PERIOD: 1957-1966

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
NNE	4.7	5.5	5.1	5.7	5.3	4.9	4.2	4.2	5.1	5.1	4.2	4.2	4.9
NE	3.8	4.5	4.7	5.6	5.5	4.6	4.1	4.2	4.9	4.0	4.9	3.9	4.6
ENE	5.6	5.5	5.8	6.6	6.2	6.1	4.6	5.1	5.4	5.9	5.1	5.4	5.6
E	5.0	5.1	5.6	6.3	6.3	5.5	4.8	5.0	5.5	4.5	5.1	4.5	5.3
ESE	6.5	6.1	7.2	6.5	7.0	6.0	5.5	5.6	5.8	5.1	5.8	5.8	6.1
SE	6.6	7.1	7.6	7.4	7.6	6.6	5.6	5.9	6.3	6.1	6.3	7.1	6.7
SSE	6.3	6.2	7.0	7.4	7.4	6.9	5.6	5.7	7.0	6.3	6.4	6.0	6.5
S	3.8	4.3	5.1	5.8	6.5	5.5	4.6	4.6	5.3	5.3	5.2	4.0	5.0
SSW	4.5	4.6	5.1	5.8	6.6	6.1	4.3	5.1	5.5	5.5	5.3	4.5	5.2
SW	5.5	4.7	4.6	6.4	6.1	5.6	4.3	5.2	5.5	5.3	5.6	5.5	5.4
WSW	6.8	5.4	5.2	7.0	7.6	6.8	5.8	5.8	6.7	5.9	6.2	5.8	6.3
W	6.4	5.9	5.5	7.2	7.5	6.1	5.0	5.7	6.4	5.7	5.9	6.0	6.1
WNW	7.5	7.2	7.2	7.9	8.6	6.8	6.2	6.3	6.9	7.1	7.4	7.5	7.2
NW	7.5	7.1	6.9	8.0	7.2	5.8	5.6	6.1	7.2	6.8	7.9	7.7	7.0
NNW	8.1	7.2	7.1	7.6	7.3	5.7	5.5	5.6	7.2	7.0	6.7	7.6	6.9
N	5.8	5.5	5.5	5.9	6.3	5.1	4.2	4.2	5.8	5.9	5.1	5.1	5.4
AVG	6.5	6.2	6.5	6.8	6.9	5.9	5.1	5.3	6.3	5.9	6.1	6.3	6.2

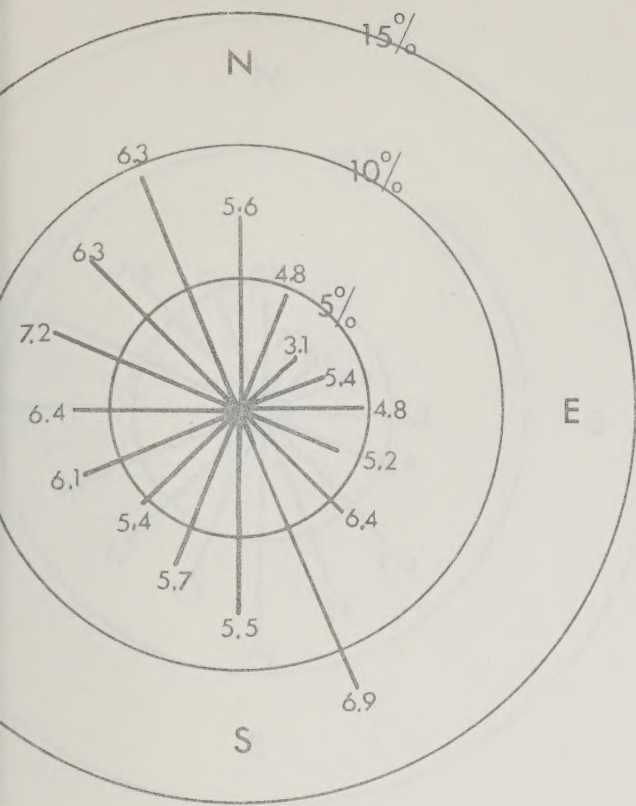
TABLE A.10

MEAN MONTHLY WIND SPEED
BY DIRECTION
(M/S)

STATION: MOOSE JAW A SASK.

PERIOD: 1957-1966

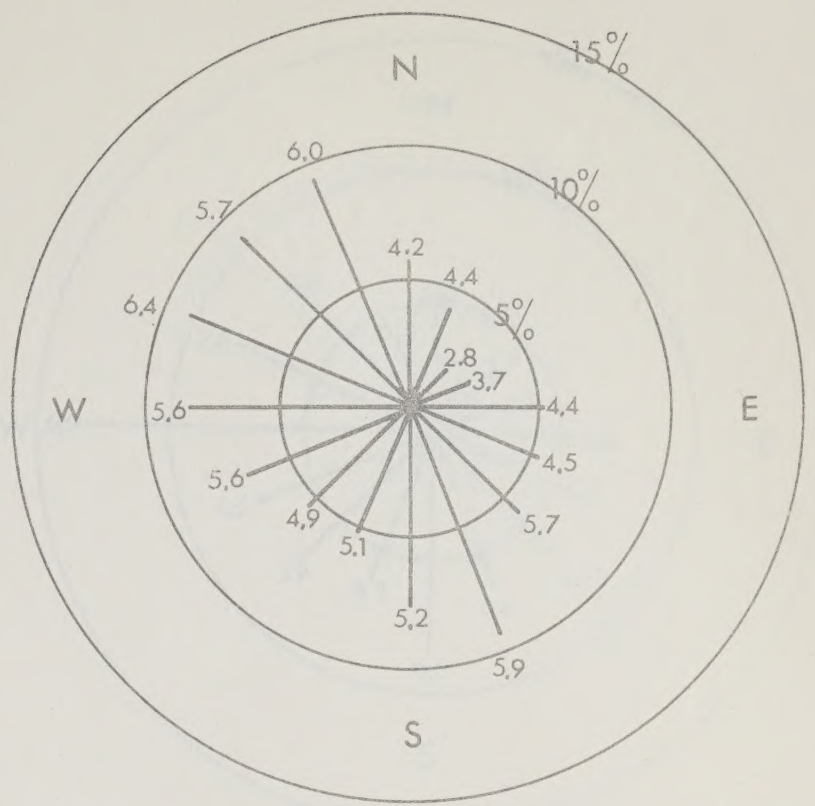
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
NNE	6.2	5.9	5.9	6.3	6.3	5.9	5.0	4.8	5.3	5.5	4.8	4.7	5.6
NE	4.3	4.2	4.1	5.0	5.2	5.2	4.3	4.7	5.1	4.9	4.3	3.8	4.6
ENE	4.6	4.4	4.3	5.9	5.9	5.6	3.9	5.1	4.8	5.9	5.1	4.5	5.0
E	4.1	3.9	4.4	6.0	5.9	4.9	4.3	4.6	5.6	4.1	4.8	4.1	4.7
ESE	5.8	6.2	6.3	6.3	6.6	6.5	6.0	5.8	6.6	5.9	5.8	5.9	6.1
SE	6.3	6.3	7.2	6.8	7.6	7.1	5.6	6.2	6.5	6.1	5.9	6.2	6.5
SSE	5.3	5.1	6.7	7.3	7.0	6.6	5.8	6.0	7.0	6.3	5.6	5.6	6.2
S	5.5	5.8	6.3	6.4	6.9	6.1	5.5	5.3	6.3	6.3	6.2	5.5	6.0
SSW	8.2	7.6	7.6	7.0	7.5	6.8	6.3	6.2	6.7	7.1	8.0	7.2	7.2
SW	8.3	8.6	7.2	7.1	7.4	6.7	5.9	6.5	7.0	7.5	8.3	8.5	7.4
WSW	8.0	8.0	7.4	7.4	7.8	7.3	6.4	6.5	7.0	7.2	7.5	8.1	7.4
W	7.6	6.7	6.6	7.7	8.3	7.1	5.9	6.4	7.0	6.9	7.3	7.3	7.1
WNW	8.0	7.3	7.5	7.8	8.1	7.2	6.7	6.8	7.6	7.5	7.8	8.1	7.5
NW	8.5	7.9	7.3	7.9	7.7	6.6	6.3	6.2	7.8	7.5	8.1	8.0	7.5
NNW	7.4	7.4	7.0	7.6	7.3	6.3	5.5	5.7	7.6	6.6	6.9	7.5	6.9
N	5.2	6.0	5.5	6.7	6.4	5.5	5.0	5.0	6.4	6.3	5.5	5.0	5.7
AVG	6.8	6.4	6.4	6.7	6.9	6.2	5.3	5.5	6.6	6.5	6.5	6.6	6.4



SPRING (MAR-MAY)

MEAN 5.9 m/s

CALM 0.3%



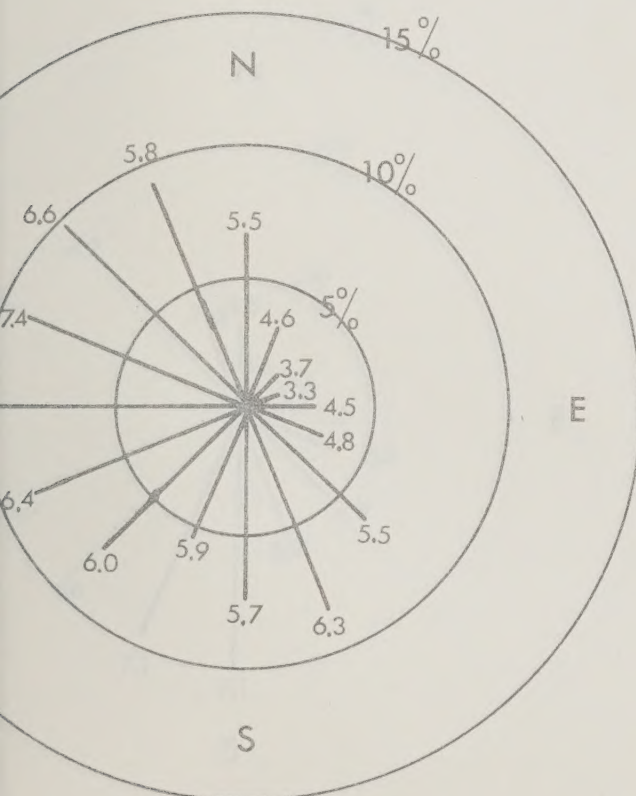
SUMMER (JUN-AUG)

MEAN 5.3 m/s

CALM 0.5%

FIGURE A1
SEASONAL WIND ROSES

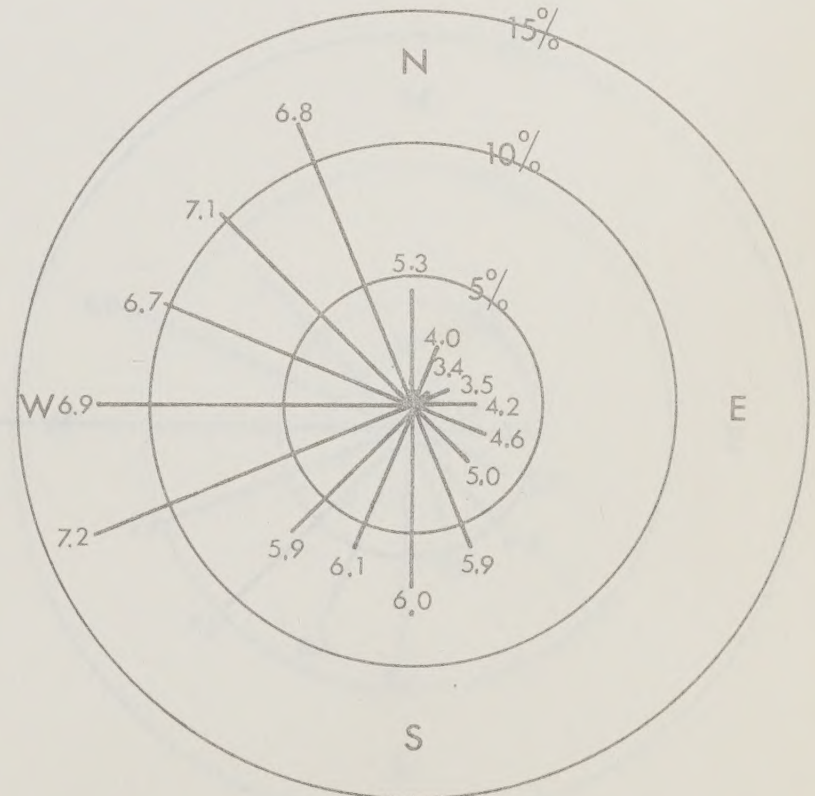
ROCKGLEN SASK. (1971-1973)



AUTUMN (SEP-NOV)

MEAN 6.0 m/s

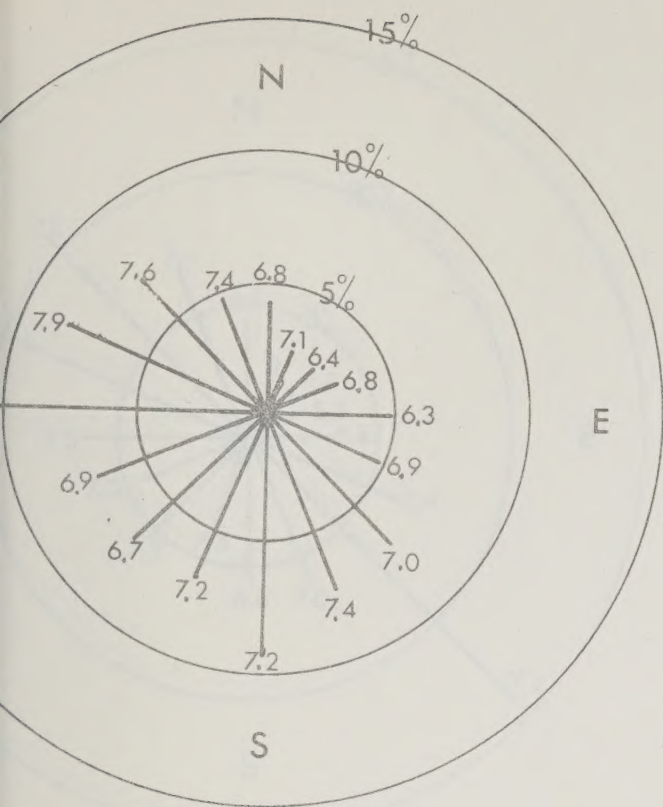
CALM 0.2%



WINTER (DEC-FEB)

MEAN 6.3 m/s

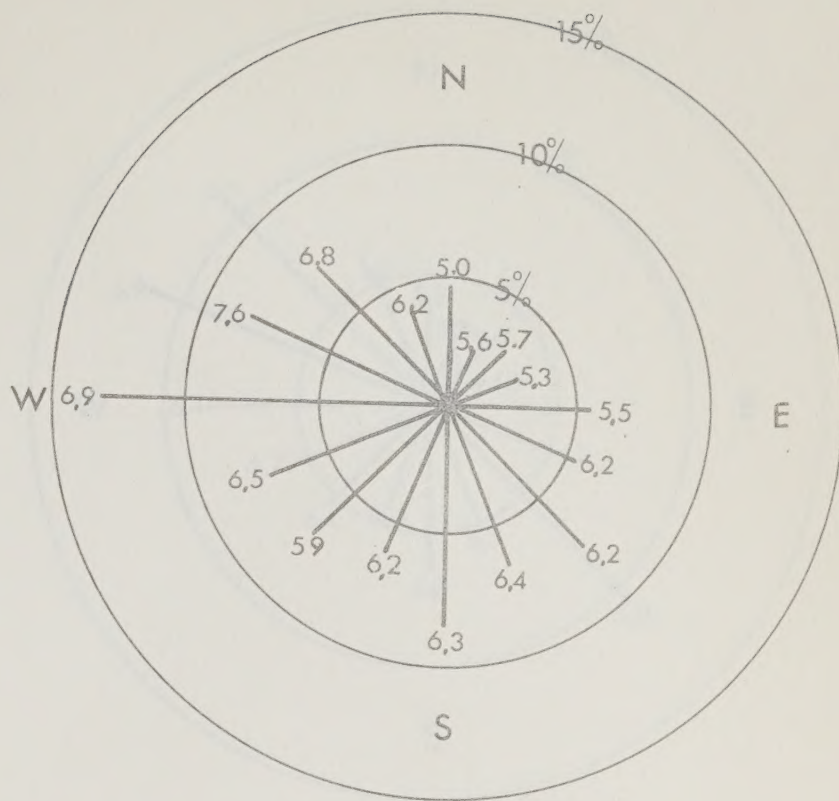
CALM 0.3%



SPRING

MEAN 7.0 m/s

CALM 1.9%



SUMMER

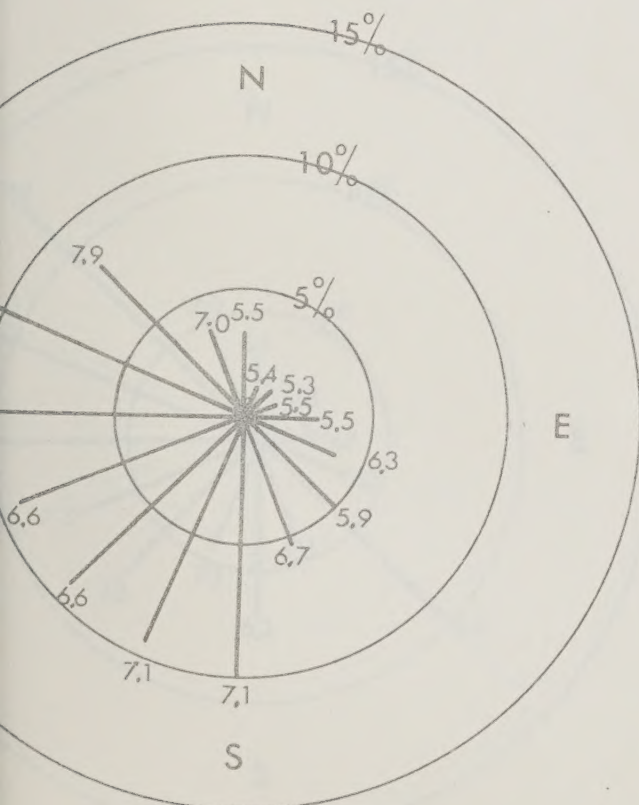
MEAN 6.2 m/s

CALM 2.2%

FIGURE A2

SEASONAL WIND ROSES

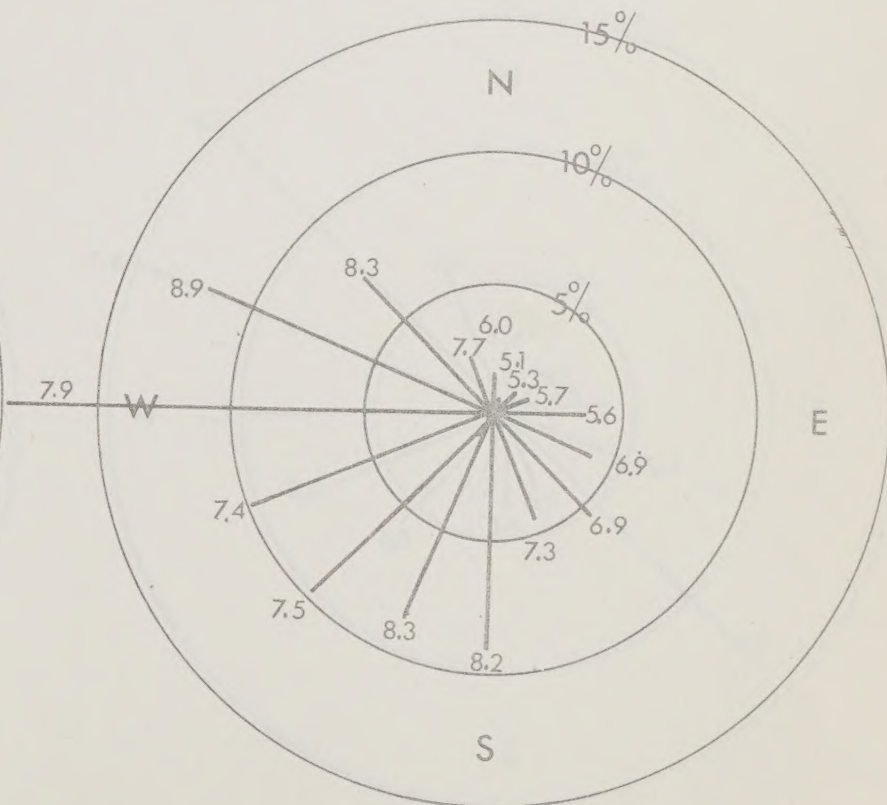
SWIFT CURRENT A SASK. (1964-1973)



AUTUMN

MEAN 6.8 m/s

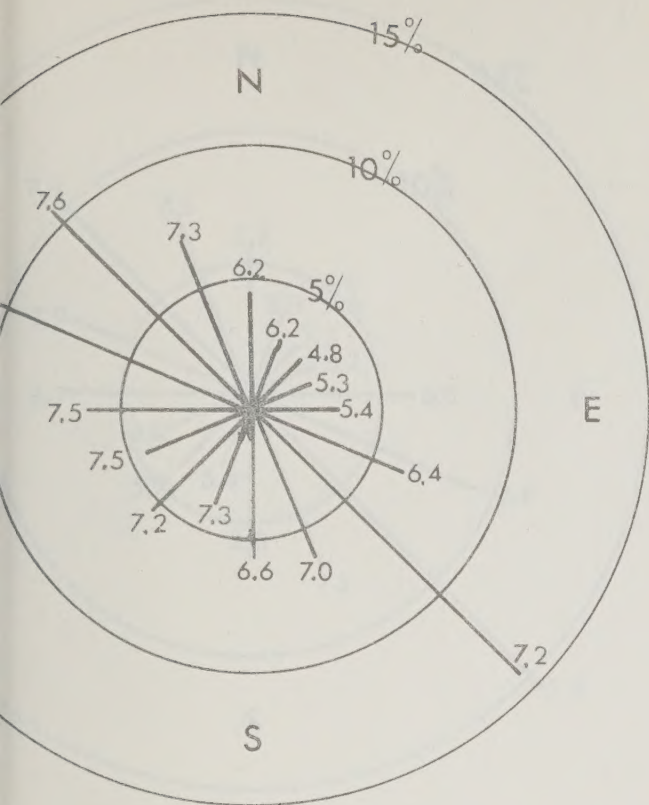
CALM 2.0%



WINTER

MEAN 7.6 m/s

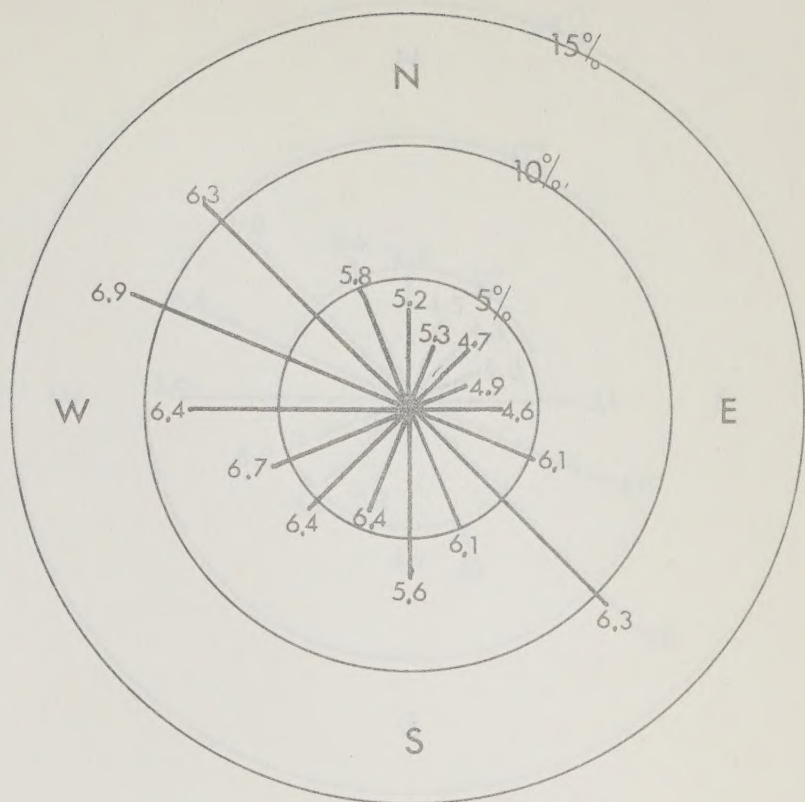
CALM 1.7%



SPRING

MEAN 6.7 m/s

CALM 5.0%



SUMMER

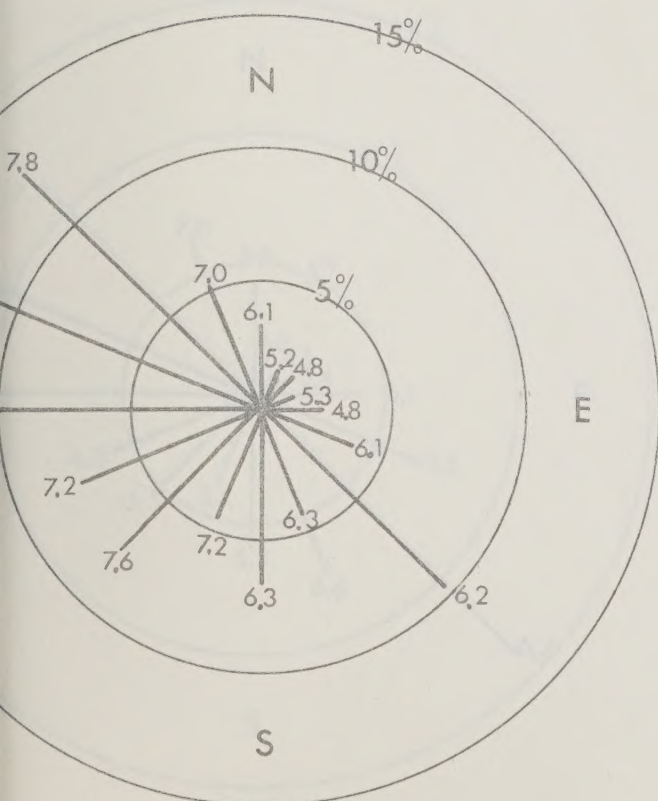
MEAN 5.7 m/s

CALM 7.3%

FIGURE A3

SEASONAL WIND ROSES

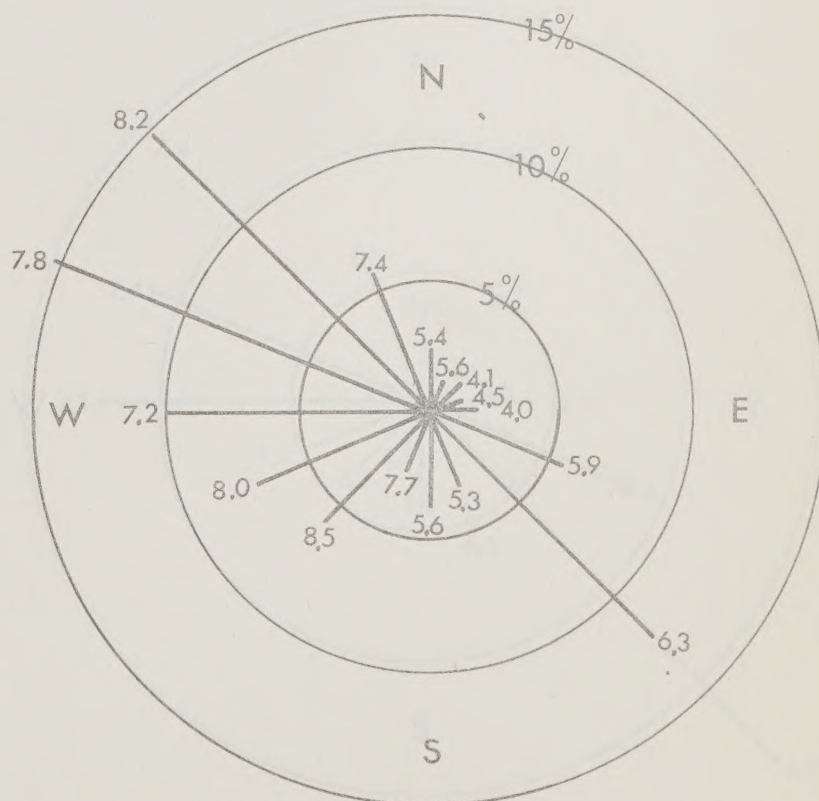
MOOSE JAW SASK. (1957-1966)



AUTUMN

MEAN 6.5 m/s

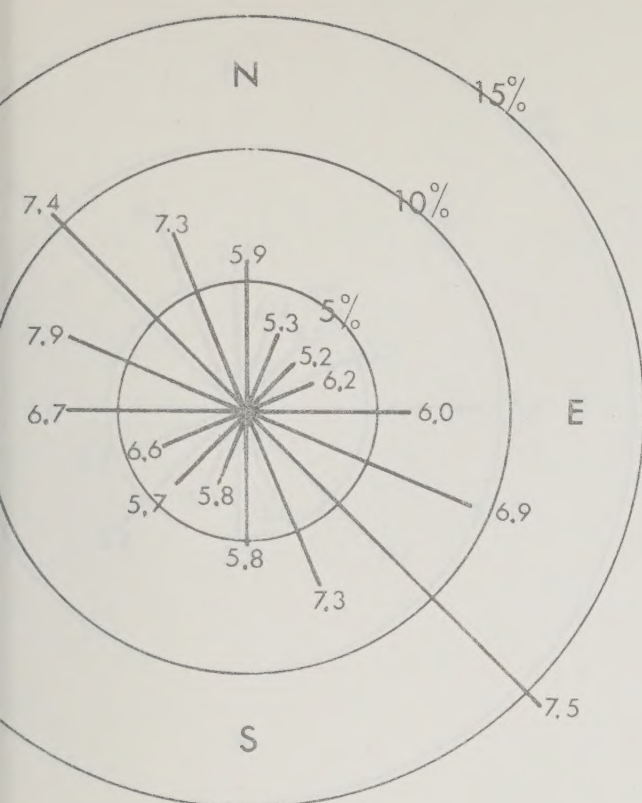
CALM 5.6%



WINTER

MEAN 6.6 m/s

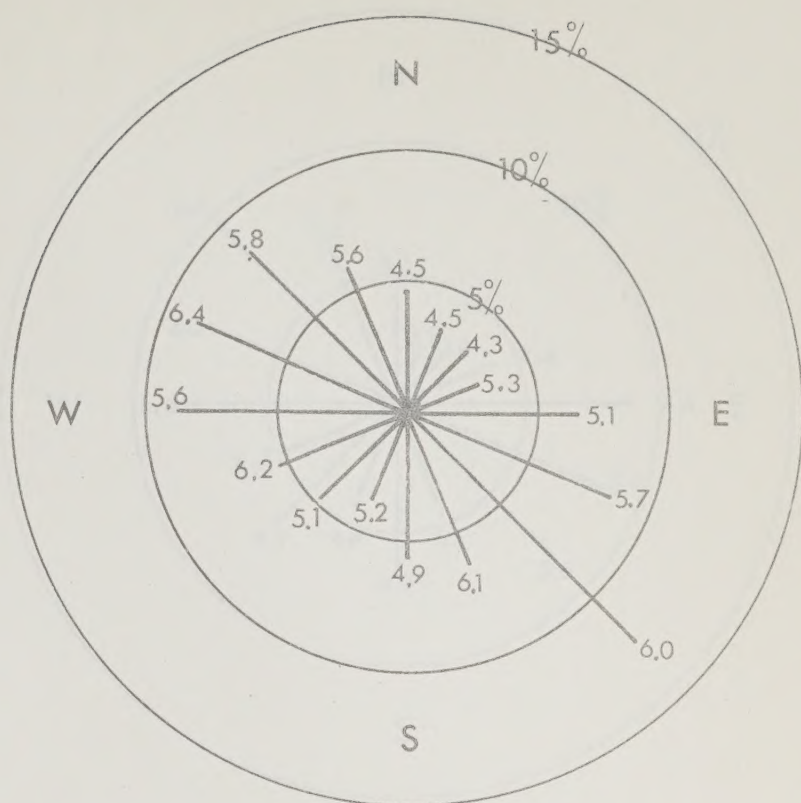
CALM 7.3%



SPRING

MEAN 6.7 m/s

CALM 1.2%

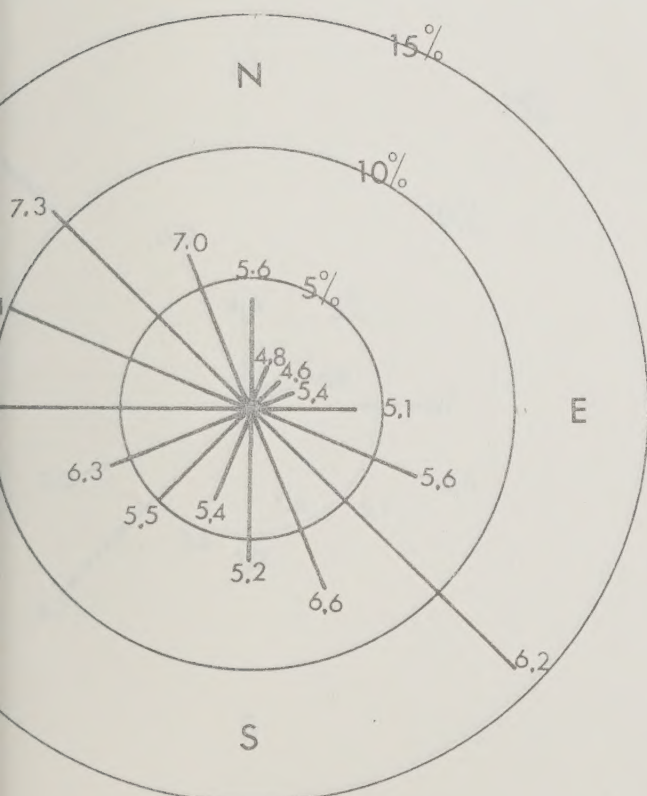


SUMMER

MEAN 5.5 m/s

CALM 1.8%

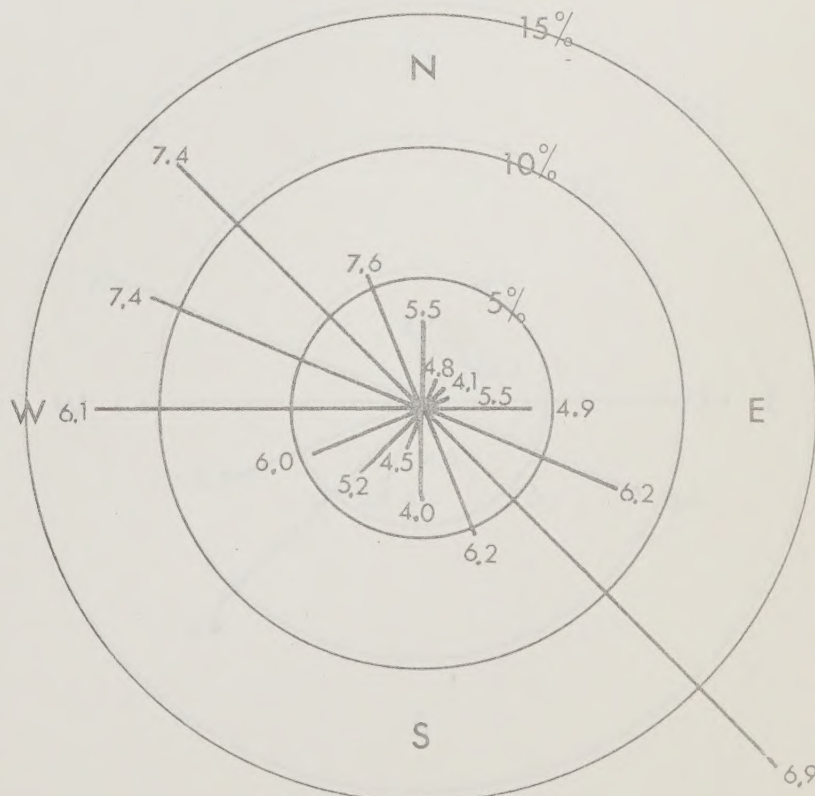
FIGURE A4
REGINA A SASK. (1957-1966)
SEASONAL WIND ROSES



AUTUMN

MEAN 6.8 m/s

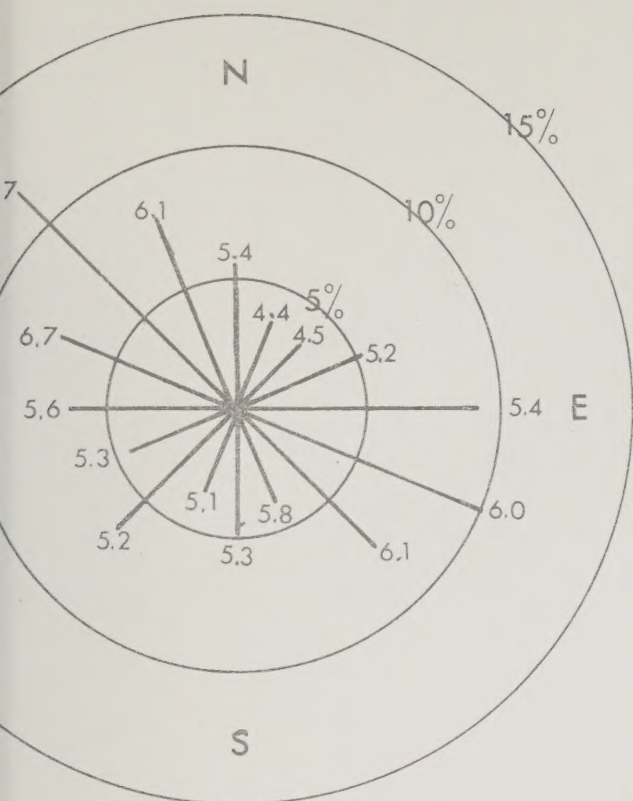
CALM 1.3%



WINTER

MEAN 7.6 m/s

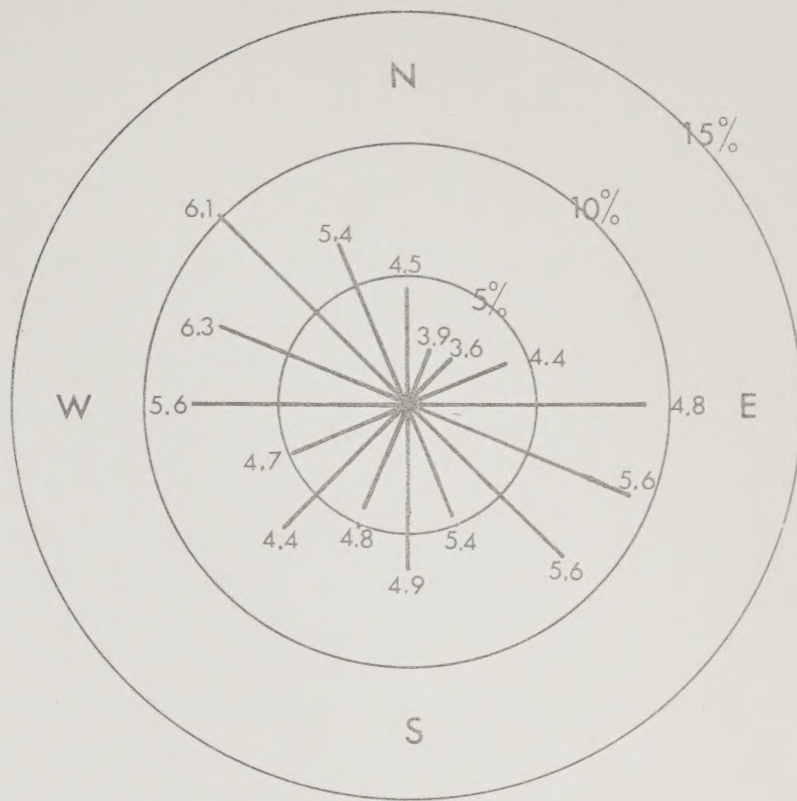
CALM 2.2%



SPRING

MEAN 5.7 m/s

CALM 0.8%

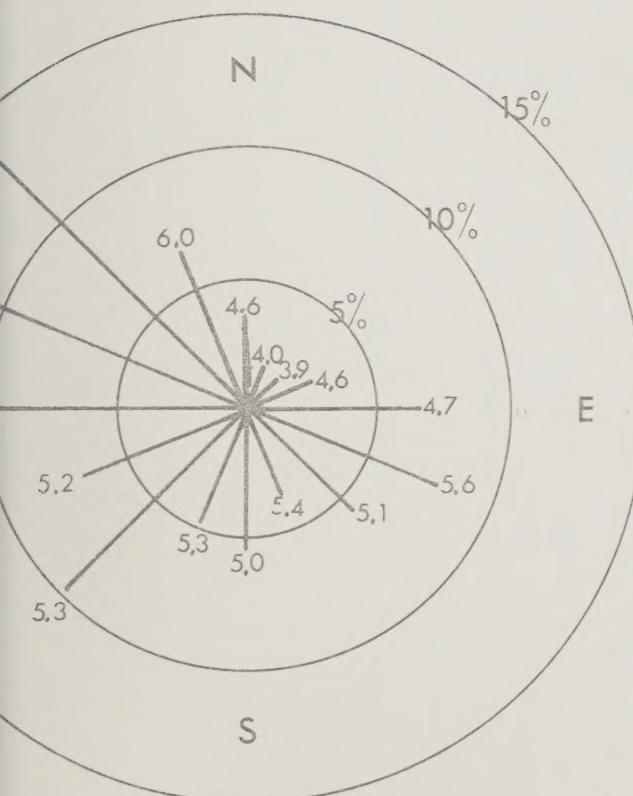


SUMMER

MEAN 5.1 m/s

CALM 1.2%

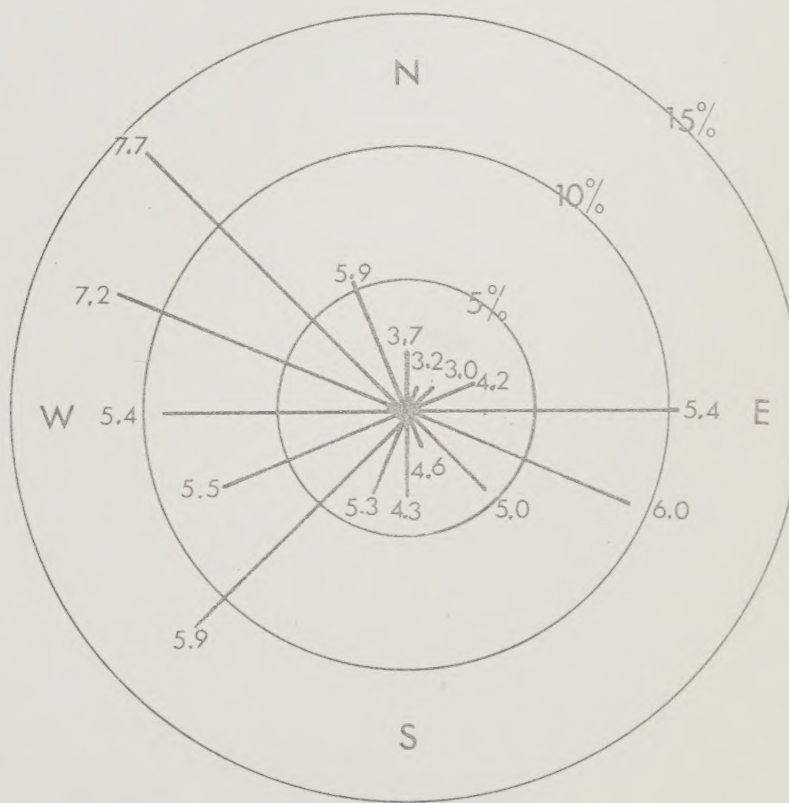
FIGURE A5
SEASONAL WIND ROSES
ESTEVAN A SASK. (1964-1973)



AUTUMN

MEAN 5.6 m/s

CALM 0.7%



WINTER

MEAN 5.8 m/s

CALM 1.2%

TABLE B.1
FREQUENCIES OF OCCURRENCE OF SPECIFIED MAXIMUM MIXING
HEIGHTS AT GLASGOW, MONTANA (JULY 1965 TO JUNE 1969)
(VALUES IN %)

M O N T A L	MAXIMUM (AFTERNOON) MIXING HEIGHTS (METRES) - ALL WIND DIRECTIONS												T O T A L
	NO MIXING	001 TO 199	200 TO 399	400 TO 599	600 TO 799	800 TO 999	1000 TO 1199	1200 TO 1399	1400 TO 1599	1600 TO 1799	1800 TO 1999	2000 +	
JAN	12.7	33.6	42.7	9.1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
FEB	7.8	33.3	42.2	9.8	4.9	1.0	0.0	1.0	0.0	0.0	0.0	0.0	100.0
MAR	9.3	11.2	25.2	16.8	8.4	1.9	4.7	5.6	4.7	3.7	3.7	4.7	100.0
APR	7.0	2.6	3.5	11.4	7.9	5.3	13.2	5.3	5.3	5.3	6.1	27.2	100.0
MAY	2.6	0.0	5.1	1.7	7.7	6.0	6.0	6.0	6.8	9.4	8.5	40.2	100.0
JUN	2.5	5.9	4.2	2.5	8.5	4.2	10.2	4.2	8.5	3.4	8.5	37.3	100.0
JUL	0.8	0.8	1.7	4.2	6.8	5.1	5.1	3.4	10.2	8.5	7.6	45.8	100.0
AUG	1.8	0.9	2.6	7.9	11.4	6.1	2.6	3.5	10.5	1.8	8.8	42.1	100.0
SEP	2.6	1.7	6.0	10.3	9.5	11.2	9.5	8.6	12.1	7.8	5.2	15.5	100.0
OCT	1.8	6.3	8.1	14.4	13.5	7.2	12.6	11.7	9.0	1.2	4.5	9.0	100.0
NOV	7.1	15.0	25.7	24.8	14.2	5.3	1.8	3.5	1.8	0.9	0.0	0.0	100.0
DEC	11.7	25.2	41.4	11.7	8.1	0.9	0.9	0.0	0.0	0.0	0.0	0.0	100.0
YEAR	5.6	11.0	16.9	10.3	8.6	4.6	5.6	4.4	5.8	3.6	4.5	19.0	100.0

TABLE B.2 FREQUENCIES OF OCCURRENCE OF SPECIFIED MAXIMUM MIXING
HEIGHTS AT GLASGOW, MONTANA (JULY 1965 TO JUNE 1969).
(VALUES IN %)

M O N T H	MAXIMUM (AFTERNOON) MIXING HEIGHTS (METRES) - WINDS FROM 290° TO 80°												T O T A L
	NO MIXING	001 TO 199	200 TO 399	400 TO 599	600 TO 799	800 TO 999	1000 TO 1199	1200 TO 1399	1400 TO 1599	1600 TO 1799	1800 TO 1999	2000 +	
JAN	0.9	17.3	11.8	7.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.2
FEB	0.0	14.7	10.8	4.9	3.9	0.0	0.0	1.0	0.0	0.0	0.0	0.0	35.3
MAR	0.0	7.5	12.2	8.4	3.7	0.9	2.8	1.9	3.7	1.9	1.9	0.0	44.9
APR	0.0	1.8	3.5	7.9	2.6	2.6	6.1	1.8	1.8	1.8	3.5	10.5	43.9
MAY	0.0	0.0	4.3	0.9	4.3	4.3	5.1	2.6	2.6	7.7	1.7	17.9	51.4
JUN	1.7	4.3	2.6	1.7	5.9	2.6	6.8	1.7	4.3	2.6	5.9	17.0	57.1
JUL	0.0	0.9	1.7	0.0	4.2	2.5	3.4	0.9	5.9	0.9	2.5	17.8	40.7
AUG	0.9	0.9	2.7	6.2	7.0	4.4	0.9	3.5	1.8	0.0	5.3	16.7	50.3
SEP	0.0	1.7	5.2	6.0	6.0	6.9	1.7	6.9	3.5	2.6	2.6	4.3	47.4
OCT	0.0	4.5	4.5	9.9	9.0	0.9	4.5	3.6	3.6	0.0	3.6	4.5	48.6
NOV	0.0	6.2	7.1	11.5	6.2	0.9	1.8	1.8	0.9	0.0	0.0	0.0	36.4
DEC	0.0	16.2	9.9	4.5	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	34.2
YEAR	0.3	6.1	6.2	5.7	4.7	2.3	2.8	2.2	2.4	1.5	2.3	7.6	44.1

A. Stack Data

STACK PARAMETERS	PLANT 1-12-84		
	000	001	002
NO. OF STACKS	1	1	1
STACK HEIGHT (ft)	100	100	100
STACK DIAMETER (ft)	3.0	3.0	3.0
STACK GAS EXIT VELOCITY (ft/s)	10.0	10.0	10.0
STACK GAS EXIT TEMPERATURE (°C)	150.0	150.0	150.0

B. Emission Data

- (i) General Information APPENDIX C
- a) Total Production = 100,000 lb/hr
 - b) Total Pollutant Value = 1000 lb/hr
 - c) STACK AND EMISSION DATA

- (ii) Suspended Solids
- a) Suspended Solids in Gas = 100
 - b) Suspended Solids in Ash = 1000 lb/hr
 - c) Suspended Solids in Sludge = 1000 lb/hr
 - d) Suspended Solids in Water = 1000 lb/hr
 - e) Suspended Solids in Other = 1000 lb/hr
- (iii) Suspended Solids
- a) Suspended Solids in Gas = 100
 - b) Suspended Solids in Ash = 1000 lb/hr
 - c) Suspended Solids in Sludge = 1000 lb/hr
 - d) Suspended Solids in Water = 1000 lb/hr
 - e) Suspended Solids in Other = 1000 lb/hr

- (iv) Suspended Solids
- a) Suspended Solids in Gas = 100
 - b) Suspended Solids in Ash = 1000 lb/hr
 - c) Suspended Solids in Sludge = 1000 lb/hr
 - d) Suspended Solids in Water = 1000 lb/hr
 - e) Suspended Solids in Other = 1000 lb/hr

Stack and Emission Data - Poplar River Thermal Power Station

A. Stack Data

STACK PARAMETERS	PLANT SIZE (MW)		
	300	600	1200
NO OF STACKS	1	1	2
STACK HEIGHT (m)	129.5	122.0	122.0
STACK DIAMETER (m)	5.03	7.11	7.11
STACK GAS EXIT VELOCITY (m/s)	24.4	24.4	24.4
STACK GAS EXIT TEMPERATURE (°C)	151.7	151.7	151.7

B. Emission Data

(i) General information:

- a) Coal consumption - 495,000 lb/hr
- b) Coal calorific value - 5800 BTU/lb
- c) Heat input - 3000×10^6 BTU/hr

(ii) Suspended Particulates:

- a) Percentage ash in coal - 13%
- b) Dust loading to ESP - 70% = 45,000 lb/hr
- c) Controlled emission rates per
300 MW on various ESP design
efficiencies

96% - 1800 lb/hr or 227 g/s (= 0.60 lb/10⁶ BTU)

98% - 900 lb/hr or 114 g/s (= 0.30 lb/10⁶ BTU)

99% - 450 lb/hr or 57 g/s (= 0.15 lb/10⁶ BTU)

99.5% - 225 lb/hr or 28 g/s (= 0.08 lb/10⁶ BTU)

(iii) Sulphur Dioxide:

- a) Sulphur - 0.5% (as received)
- b) 40% sulphur retained in ash
- c) SO₂ emission rate per 300 MW
is 3000 lb/hr or 378 g/s

(iv) Nitrogen Oxides:

a) 400 ppm NO_x calculated as NO₂ @ 3% oxygen

b) NO₂ emission rate^{*} per 300 MW is 1800 lb/hr
or 227 g/s

* Yet to be confirmed by Saskatchewan Power Corp.

APPENDIX D

LIMITED MIXING CALCULATIONS

LIMITED MIXING CALCULATIONS

The following method of estimating ground-level concentrations has been suggested by Turner (1970). A plume whose centerline is initially within the mixed layer will spread vertically until its upper edge reaches the mixing height. (The edge of the plume at a given downwind distance is defined as that point at which the concentration of pollutants is one-tenth that at the centerline. This point is at a distance of $2.15 \sigma_z$ from the centerline of the plume, where σ_z is the standard deviation of the plume in the vertical, as given by Pasquill (1961) and Gifford (1961)). When the upper edge of the plume reaches the mixing height, it is reasonable to assume that the distribution of the pollutants within the mixed layer is being affected by the "lid". On the average, this occurs when σ_z is equal to $L/2.15$ or $0.47L$. At this distance X_L , the plume is assumed to have a Gaussian distribution in the vertical. Beyond $X=X_L$, there is assumed to be vertical reflection of the plume between the "lid" and the ground so that, by the time the plume has travelled a downwind distance of $2X_L$, the plume is assumed to be uniformly distributed in the vertical between the earth's surface and the mixing height L , i.e., concentration does not vary with height. At this distance, the ground level concentration is at a maximum (see Fig. 6). Beyond $2X_L$ the concentration decreases slowly with increasing distance since the plume can still spread horizontally. The concentration $x_{\max}$ at distance $2X_L$ along the plume centerline, averaged over one hour, is given by:

$$X_{\max} = \frac{cQ}{\sqrt{2\pi}\sigma_y Lu}$$

where Q = source strength (grams/sec)

σ_y = the Pasquill-Gifford crosswind standard deviation
(meters) at downwind distance $X=2X_L$

L = mixing height (meters)

u = mean wind speed (meters/sec) within the mixed layer

c = time-averaging factor (see p.37 Turner, 1970)

